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ERRATA.—In the article on the Belt Dynamometer, of Dr. C. W. Siemens, in the JOURNAL for July, 1880, page 5, read, "This dynamometer, with the proportions given, *when running at the rate of* 120 *revolutions per minute*, and on the supposition that 6-inch belts be used, will transfer, if the belt is strained normally upon both sides to 40·4 pounds per inch of width, 7·2 horse-power."

motion of viscous incompressible fluids. It was not possible on that occasion to give in detail the analytical processes which were employed in making the necessary reductions and transformations; so the present paper has been prepared for the purpose of giving the results mentioned before the Association, and also the methods of arriving at them. The equations of motion of a viscous incompressible fluid are

$$\begin{aligned} \rho \frac{Du}{Dt} &= \rho X - \frac{dp}{dx} + \mu \Delta^2 u, \\ \rho \frac{Dv}{Dt} &= \rho Y - \frac{dp}{dy} + \mu \Delta^2 v, \\ \rho \frac{Dw}{Dt} &= \rho Z - \frac{dp}{dz} + \mu \Delta^2 w, \end{aligned} \tag{1}$$

where u, v, w denote the component velocities of a particle at the point

New Welding Process.—Krupp has recently taken out a German patent for a new process of welding tubes and tires. He draws the tube on a pair of ordinary rolls and heats the whole length of the portions which are to be welded in a portable fire-box, into which air is blown so that the heat is directed against the weld. After the necessary heat is obtained the rolls are set in motion and the place which is to be welded is repeatedly drawn through them.—*L'Ingen. Univ.* C.

Accuracy of Glass Gauge-tubes.—In his experiments upon compressibility Amagat employs for manometers glass tubes of about 1 mm. (0·4 in.) internal diameter, and 10 to 12 mm. (·39 to ·47 in.)

that modern scientific methods thus confirm the inspirations of a skillful architect whose numerous domes were projected by feeling rather than by mathematical knowledge.—*Bull. de la Soc. d'Encour.* C.

Profit of Public Works.—M. de Labry has written an essay, in which he discusses the various advantages of public improvements to invested capital, to adjacent regions, and to the government, showing that the dividends to stockholders and the direct revenues of government constitute only a small portion of the benefits conferred by increased facilities for travel and the transportation of merchandise. He thinks that both self-interest and duty should prompt the inhabitants of regions which have been well developed to contribute towards the opening of new districts. Even if the contributions appear to be sunk, the increase of trade and of general prosperity will, almost without exception, amply repay all the outlay.—*Ann. des Ponts et Chauss.* C.

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MOTION OF VISCOUS FLUIDS.

By Dr. THOMAS CRAIG.

United States Coast and Geodetic Survey.

In a paper read before the American Association for the Advancement of Science, at its recent meeting in Boston, I mentioned some results which I had obtained in the course of an investigation of the motion of viscous incompressible fluids. It was not possible on that occasion to give in detail the analytical processes which were employed in making the necessary reductions and transformations; so the present paper has been prepared for the purpose of giving the results mentioned before the Association, and also the methods of arriving at them. The equations of motion of a viscous incompressible fluid are

$$\begin{aligned} \rho \frac{Du}{Dt} &= \rho X - \frac{dp}{dx} + \mu \Delta^2 u, \\ \rho \frac{Dv}{Dt} &= \rho Y - \frac{dp}{dy} + \mu \Delta^2 v, \\ \rho \frac{Dw}{Dt} &= \rho Z - \frac{dp}{dz} + \mu \Delta^2 w, \end{aligned} \tag{1}$$

where u, v, w denote the component velocities of a particle at the point

x, y, z, p the pressure at that point, μ the coefficient of viscosity, ρ the constant density of the fluid and X, Y, Z external forces. The operator $\frac{D}{Dt}$ of course indicates total differentiation with respect to the time. To these is to be added the equation

$$\frac{du}{dx} + \frac{dv}{dy} + \frac{dw}{dz} = 0 \tag{2}$$

expressing the continuity of the fluid. On account of the viscosity of the fluid the motion will be in part rotational; designating by ξ, η, ζ the components of angular velocity at the point x, y, z, these quantities are defined by the equations

$$\begin{aligned} \xi &= \tfrac{1}{2}\left(\frac{dw}{dy} - \frac{dv}{dz}\right), \\ \eta &= \tfrac{1}{2}\left(\frac{du}{dz} - \frac{\partial w}{dx}\right), \\ \zeta &= \tfrac{1}{2}\left(\frac{dv}{dx} - \frac{du}{dy}\right). \end{aligned} \tag{3}$$

The following relations, which are readily deduced from these, are frequently of value:

$$\begin{aligned} \Delta^2 u &= 2\left(\frac{d\eta}{dz} - \frac{d\zeta}{dy}\right), \\ \Delta^2 v &= 2\left(\frac{d\zeta}{dx} - \frac{d\xi}{dz}\right), \\ \Delta^2 w &= 2\left(\frac{d\xi}{dy} - \frac{dy}{dx}\right). \end{aligned} \tag{4}$$

Denote by Ω the resultant angular velocity; then

$$\Omega^2 = \xi^2 + \eta^2 + \zeta^2; \tag{5}$$

Also write

$$2q = u^2 + v^2 + w^2. \tag{6}$$

Performing the differentiations necessary to determine the form of $\Delta^2 q$, we readily find for this quantity the expression

$$\begin{aligned} \Delta^2 q = u\Delta^2 u + v\Delta^2 v + w\Delta^2 w &+ \left(\frac{du}{dx}\right)^2 + \left(\frac{du}{dy}\right)^2 + \left(\frac{du}{dz}\right)^2 \\ &+ \left(\frac{dv}{dx}\right)^2 + \left(\frac{dv}{dy}\right)^2 + \left(\frac{dv}{dz}\right)^2 \\ &+ \left(\frac{dw}{dx}\right)^2 + \left(\frac{dw}{dy}\right)^2 + \left(\frac{dw}{dz}\right)^2, \end{aligned} \tag{7}$$

which, as we shall presently see, can be written in a much briefer form. Write for brevity

$$\begin{aligned} a &= \frac{du}{dx}, & f &= \tfrac{1}{2}\left(\frac{dw}{dy}+\frac{dv}{dz}\right), \\ b &= \frac{dv}{dy}, & g &= \tfrac{1}{2}\left(\frac{du}{dz}+\frac{dw}{dx}\right), \\ c &= \frac{dw}{dz}, & h &= \tfrac{1}{2}\left(\frac{dv}{dx}+\frac{du}{dy}\right). \end{aligned} \tag{8}$$

The internal friction involves a certain dissipation of energy; the function expressing the rate of dissipation per unit volume has been called by Lord Rayleigh the "dissipation-function"; denoting this quantity by E, we have

$$E = 2\mu\,(a^2+b^2+c^2+2f^2+2g^2+2h^2). \tag{9}$$

In order to obtain the rate of dissipation of energy throughout the entire space filled by the fluid it will be necessary to perform the integration

$$\iiint E\,dx\,dy\,dz$$

throughout that region.

Equations (3), (5), (7) and (8) now give

$$u\,\nabla^2 u+v\,\nabla^2 v+w\,\nabla^2 w=\nabla^2 q-\frac{1}{2}\,\mu\,E-2\Omega^2 \tag{10}$$

or

$$E = 2\mu\left\{\nabla^2 q-(u\,\nabla^2 u+v\,\nabla^2 v+w\,\nabla^2 w)-4\Omega^2\right\} \tag{11}$$

If we suppose that the forces X, Y, Z possess a potential, we may write

$$X=-\frac{dV}{dx},\quad Y=-\frac{dV}{dy},\quad Z=-\frac{dV}{dz};$$

furthermore, it is easily seen that

$$\frac{Du}{Dt}=\frac{du}{dt}+u\frac{du}{dx}+v\frac{dv}{dx}+w\frac{dw}{dx}+2(w\eta-v\zeta), \text{ etc.}$$

Making these substitutions in equations (1) and they become

$$\begin{aligned}
\frac{du}{dt} + \frac{d(V+q)}{dx} + \frac{1}{\rho}\frac{dp}{dx} + 2(w\eta - v\zeta) &= \frac{\mu}{\rho}\nabla^2 u,\\
\frac{dv}{dt} + \frac{d(V+q)}{dy} + \frac{1}{\rho}\frac{dp}{dy} + 2(u\zeta - w\xi) &= \frac{\mu}{\rho}\nabla^2 v, \qquad (12)\\
\frac{dw}{dt} + \frac{d(V+q)}{dz} + \frac{1}{\rho}\frac{dp}{dz} + 2(v\xi - u\eta) &= \frac{\mu}{\rho}\nabla^2 w.
\end{aligned}$$

In the case of steady motion the first term in the left hand member of each of these equations vanishes, and for this case we have as the differential equations of motion

$$\begin{aligned}
\frac{dP}{dx} + 2(w\eta - v\zeta) &= k\nabla^2 u,\\
\frac{dP}{dy} + 2(u\xi - w\xi) &= k\nabla^2 v, \qquad (13)\\
\frac{dP}{dz} + 2(v\xi - u\eta) &= k\nabla^2 w,
\end{aligned}$$

when k (the kinematic coefficient of viscosity) $= \frac{\mu}{\rho}$ and

$$P = V + q + \int\frac{dp}{\rho}.$$

If we assume that the quantities $\nabla^2 u$, $\nabla^2 v$, $\nabla^2 w$ are the first differential coefficients with respect to x, y and z of a function, Q, these equations become

$$\begin{aligned}
\frac{d(P-kQ)}{dx} &= -2(w\eta - v\zeta),\\
\frac{d(P-kQ)}{dy} &= -2(u\zeta - w\xi), \qquad (14)\\
\frac{d(P-kQ)}{dz} &= -2(v\zeta - u\eta).
\end{aligned}$$

Multiplying these by u, v, w, respectively, and then by ξ, η, ζ, and adding in each case, we have, writing for brevity $\theta = P - kQ$,

$$\begin{aligned}
u\frac{d\theta}{dx} + v\frac{d\theta}{dy} + w\frac{d\theta}{dz} &= 0,\\
\xi\frac{d\theta}{dx} + \eta\frac{d\theta}{dy} + \zeta\frac{d\theta}{dz} &= 0. \qquad (15)
\end{aligned}$$

and also

$$\frac{d\theta}{du} = q'\,\Omega\sin.\,\theta, \qquad (16)$$

where $q' = \sqrt{2q}$, is the current velocity and θ is the angle between the stream-line and the vortex-line at the point x, y, z.

Hence the conditions that the state of motion of the fluid for which

$$\Delta^2 u.\, dx + \Delta^2 v.\, dy + \Delta^2 w.\, dz$$

is an exact differential shall be a state of steady motion are as follows. It must be possible to draw in the fluid a system of surfaces, $\theta =$ const., infinite in number, and each of which is covered by a network of stream-lines and vortex-lines. This is the property indicated by equations (15). The product

$$q'\, \Omega \sin.\, \theta\, dn$$

must be constant over each such surface, dn denoting the length of the normal drawn to a consecutive surface of the system. In his work on Fluid Motion Professor Lamb gives results in the case of perfect fluids which are identical in form with these. The conditions to be satisfied in order that

$$\Delta^2 u.\, dx + \Delta^2 v.\, dy + \Delta^2 w.\, dz$$

shall be an exact differential are obviously

$$\begin{aligned} \Delta^2 \xi &= o, \\ \Delta^2 \eta &= o, \\ \Delta^2 \zeta &= o. \end{aligned} \tag{17}$$

These conditions may also be arrived in a different way from equations (14); the quantity

$$(w\eta - v\zeta)\, dx + (u\zeta - w\xi)\, dy + (v\xi - u\eta)\, dz$$

must be an exact differential; the conditions for this are

$$\begin{aligned} u\frac{d\xi}{dx} + v\frac{d\xi}{dy} + w\frac{d\xi}{dz} &= \xi\frac{du}{dx} + \eta\frac{du}{dy} + \zeta\frac{du}{dz} \\ u\frac{d\eta}{dx} + v\frac{d\eta}{dy} + w\frac{d\eta}{dz} &= \xi\frac{dv}{dx} + \eta\frac{dv}{dy} + \zeta\frac{dv}{dz} \\ u\frac{d\zeta}{dx} + v\frac{d\zeta}{dy} + w\frac{d\zeta}{dz} &= \xi\frac{dw}{dx} + \eta\frac{dw}{dy} + \zeta\frac{dw}{dz} \end{aligned} \tag{18}$$

The equations of vortex motion in a viscous fluid are, however, known to be

$$\frac{d\xi}{dt} + u\frac{d\xi}{dx} + v\frac{d\xi}{dy} + w\frac{d\xi}{dz} = \xi\frac{du}{dx} + \zeta\frac{du}{dy} + \eta\frac{du}{dz} + k\Delta^2\xi$$

with two similar ones. Making in these $\frac{d\xi}{dt} = \frac{d\eta}{dt} = \frac{d\zeta}{dt} = o$, we have as the necessary conditions for the existence of equations (18) since k cannot vanish,

$$\Delta^2 \xi = \Delta^2 \eta = \Delta^2 \zeta = o.$$

From equations (13) we have in every case

$$o = u\left(\frac{dP}{dx} - k\,\Delta^2 u\right) + v\left(\frac{dP}{dx} - k\,\Delta^2 v\right) + w\left(\frac{dP}{dx} - k\,\Delta^2 w\right),$$
$$o = \xi\left(\frac{dP}{dx} - k\,\Delta^2 u\right) + \eta\left(\frac{dP}{dx} - k\,\Delta^2 v\right) + \zeta\left(\frac{dP}{dx} - k\,\Delta^2 w\right). \tag{19}$$

so that the same conditions for steady motion hold now as in the particular case just mentioned; the surfaces in the fluid are, however, given by the differential equation

$$dP - k\,(\Delta^2 u.\,dx + \Delta^2 v.\,dy + \Delta^2 w.\,dz) = o. \tag{20}$$

In this general case the quantities in parentheses in the left hand members of equations (13) are not the first differential coefficients of a function x, y, z, but in equations (14) we may write

$$2\,(w\eta - v\zeta) = -\frac{d\Psi}{dx},$$
$$2\,(u\zeta - w\xi) = -\frac{d\Psi}{dy}, \tag{21}$$
$$2\,(v\xi - u\eta) = -\frac{d\Psi}{dz};$$

and since by taking the equation of continuity into account we have

$$\Delta^2 Q = o, \tag{22}$$

equations (44) give

$$\Delta^2 (P - \Psi) = o. \tag{23}$$

Any solution of (22) giving Q as a function of x, y, z will enable us to determine u, v, w by means of the equations

$$\Delta^2 u = \frac{dQ}{dx}, \quad \Delta^2 v = \frac{dQ}{dy}, \quad \Delta^2 w = \frac{dQ}{dz}.$$

Writing

$$r^2 = (x - x')^2 + (y - y')^2 + (z - z')^2$$

we have

$$u = -\frac{1}{2\pi}\iiint \frac{dQ}{dx'}\,\frac{dx'\,dy'\,dz'}{r},$$
$$v = -\frac{1}{2\pi}\iiint \frac{dQ}{dy'}\,\frac{dx'\,dy'\,dz'}{r}, \tag{25}$$
$$w = -\frac{1}{2\pi}\iiint \frac{dQ}{dz'}\,\frac{dx'\,dy'\,dz'}{r}.$$

The values of ξ, η, ζ obtained from these will necessarily satisfy the equation of condition

$$\mathcal{A}^2 \xi = \mathcal{A}^2 \eta = \mathcal{A}^2 \zeta = 0.$$

A value for p can also be obtained from (33), but for the present we will leave this part of the subject and consider the more general case where the function Q does not exist. Write for convenience

$$\begin{aligned} A &= v\zeta - w\eta, \\ B &= w\xi - u\zeta, \\ C &= u\eta - v\xi. \end{aligned}$$

Equations (13) now become

$$\begin{aligned} \frac{dP}{dx} - 2A &= k\mathcal{A}^2 u \\ \frac{dP}{dy} - 2B &= k\mathcal{A}^2 v \\ \frac{dP}{dz} - 2C &= k\mathcal{A}^2 w \end{aligned} \tag{27}$$

And from these we have

$$\mathcal{A}^2 P = 2\left(\frac{dA}{dx} + \frac{dB}{dy} + \frac{dC}{dz}\right) \tag{28}$$

It is easy to see that an equation of precisely the same form will hold in the case where the motion is not supposed to be steady; for if we differentials equations (12) for x, y, z respectively and add the terms containing the differential coefficients of u, v, w with respect to t will disappear by virtue of the equation of continuity. Integrating (28) and remembering that

$$P = V + q + \int \frac{dp}{\rho}$$

We have, since ρ is constant

$$\frac{p}{\rho} + G - \left\{ \tfrac{1}{2}\pi \iiint \left(\frac{dA}{dx'} + \frac{dB}{dy'} + \frac{dC}{dz'}\right) dx'\, dy'\, dz' + V + q \right\} \tag{29}$$

In the general case G is a function of the time for steady motion, however, it is a constant. This expression for p can be transformed into another, the form of which is rather striking. Let

$$\begin{aligned} A &= \alpha D \\ B &= \beta D \\ C &= \gamma D \end{aligned} \tag{30}$$

Then α, β, γ are the direction cosines of a vector D whose components are A, B, C. Substituting in the equation

$$D^2 = A^2 + B^2 + C^2$$

the values of A, B, C, we have readily

$$D = q'\Omega\left\{1 - \left(\frac{u\xi}{q'\Omega} + \frac{v\eta}{q'\Omega} + \frac{w\zeta}{q'\Omega}\right)^2\right\} \tag{31}$$

Or, $$D = q'\Omega \sin.\ \varphi \tag{32}$$

Where φ is the angle between the stream-line and vortex-line at the point $x\ y\ z$. Now, supposing the fluid to be contained within a rigid (or non-rigid) closed surface; let a, b, c be the direction-cosines of a normal to this surface, then

$$a\alpha + b\beta + c\gamma$$

is the sine of the angle between plane containing the instantaneous axis of rotation Ω and direction of resultant velocity q', or

$$\sin.\ \varphi = a\alpha + b\beta + c\gamma \tag{33}$$

Similarly, if we denote by a', b', c' the direction-cosines of the line joining $x\ y\ z$ to $x'\ y'\ z'$ and ρ the angle between this line and the above mentioned plane we have

$$\sin.\ \varphi' = a'\alpha + b'\beta + c'\gamma \tag{34}$$

Take now the triple integral on the right hand side of (29)

$$-\frac{1}{2\pi}\iiint\left(\frac{dA}{dx'} + \frac{dB}{dy'} + \frac{dC}{dz'}\right)\frac{dx'\,dy'\,dz'}{r}$$

This is

$$= \frac{1}{2\pi}\iiint(aA + bB + cC)\,\frac{d\sigma}{r} + \frac{1}{2\pi}\iiint(a\,A + bB + cC)\,\frac{x'\ y'\ z'}{r^2}$$

Where $d\sigma$ is an element of the bounding surface. By virtue of (30), (32), (33), (34), we have now

$$-\frac{1}{2\pi}\iiint\left(\frac{dA}{dx'} + \frac{dB}{dy'} + \frac{dC}{dz'}\right)\frac{dx'\,dy'\,dz'}{r} \tag{35}$$

$$= \iint\frac{q'\tilde{\omega} \sin.\ \theta \sin.\ \varphi}{r}\,d\sigma + \frac{1}{2\pi}\iiint\frac{q'\Omega \sin.\ \theta \sin.\ \varphi'}{r^2}\,dx'dy'dz'$$

And finally

$$\frac{p}{\rho} = G - (V + q) + \frac{1}{2\pi}\left\{\iint \frac{q'\Omega \sin.\theta \sin.\varphi}{r}\, d\sigma + \iiint \frac{q'\Omega \sin.\theta \sin.\varphi'}{r^2}\, dx'\, dy'\, dz'\right\} \quad (36)$$

If the motion in the fluid is a screw motion, *i. e.*, if the direction of motion be along the instantaneous axis of rotation we shall have $\theta = o$, and consequently

$$\frac{p}{\rho} = G - (V + q) \quad (37)$$

If the plane containing the direction of motion and instantaneous axis of rotation be always normal to the surface we shall have $\varphi = o$ and then

$$\frac{p}{\rho} = G - (V + g) + \frac{1}{2\pi}\iiint \frac{q'\pi' \sin.\theta \sin.\varphi d}{r^2}\, dx'\, dy'\, dz'\,; \quad (38)$$

and when x, y, z and $x'\ y'\ z'$ lie in this plane

$$\frac{p}{\rho} = G\ (V + q) \quad (39)$$

In an article in the *Mathematische Annalen*, entitled "Einige Betrachtungen über die Gleichungen der Hydrodynamik," by D. Bobylew, the author studies the problemn of vortex motion in viscous fluids by means of an arbitrary system of curvilinear coordinates. Among other results he arrives at that expressed by equation (36), viz., that the pressure is not an explicit function of the coefficient of viscosity. The form which he obtains for the pressure (*Math. Annalen*, Vol. vi, page 84) is identical with that given in (25). Another problem discussed by Bobylew (pages 82 and 83, *ibid.*) is the rate of variation of the kinetic energy of the fluid, but he only gives the value of this quantity for two particular cases. The coordinates chosen by Bobylew affords a noble opportunity for algebraical gymnastics, but they unfortunately give results of so complicated a character that they are not of much practical value. The following method for finding the rate of variation of the kinetic energy is at least simple and, as an investigation in rectangular co-ordinates, I believe it to be new, Bobylew's article being the only one I know of which touches on this subject. If we call K the kinetic energy we have, since q is half the square of the velocity,

$$K = \iiint q\rho\, dx\, dy\, dz \quad (40)$$

And
$$\frac{dK}{dt} = \rho \iiint \frac{dq}{dx} dx\, dy\, dz \tag{41}$$
the integration being, of course, extended throughout all the space occupied by the fluid. Take now equations (1) and multiply them by u v w respectively and add, substituting for X, Y, Z their values as differential coefficients of V, and also write
$$V + p = -J; \tag{42}$$
This gives
$$\frac{dq}{dt} = u\frac{dJ}{dx} + v\frac{dJ}{dy} + w\frac{dJ}{dz} + \frac{\mu}{\rho}(u\Delta^2 u + v\Delta^2 + w\Delta^2 w). \tag{43}$$

By virtue of the equation of continuity the first three terms on the right hand side of this equation can be placed in the form
$$\frac{d(uJ)}{dx} + \frac{d(vJ)}{dy} + \frac{d(wJ)}{dz}.$$

Integrating this expression throughout the space filled by the fluid we have
$$\iiint \left(\frac{d(uJ)}{dx} + \frac{d(vJ)}{dy} + \frac{d(wJ)}{dz}\right) dx\, dy\, dz = \iint J(au + bv + cw)\, d\sigma \tag{44}$$
a b c being the direction cosines of the normal to the bounding surface; if this surface be supposed rigid we have
$$au + bv + cw = o \tag{45}$$
and this integral therefore vanishes. Reverting now to equation (10) we have at once
$$\frac{dK}{dt} = \mu \iiint (\Delta^2 q - 2\Omega^2)\, dx\, dy\, dz - \tfrac{1}{2}\iiint E\, dx\, dy\, dz \tag{46}$$
This can only vanish on the supposition that μ and E are both zero, which can only be the case when the fluid is perfect. In making these quantities equal to zero we have
$$K = \text{Const.}$$
which is Helmholtz's theorem for perfect fluids. The integral
$$\iiint E\, dx\, dy\, dz$$
is as we know the total rate of dissipation of energy throughout the

entire fluid mass. We can give $\frac{dK}{dt}$ in another form by using the quantities A, B, C; for

$$-\left(\frac{dA}{dx}+\frac{dB}{dy}+\frac{dC}{dz}\right)=u\left(\frac{d\eta}{dz}-\frac{d\zeta}{dy}\right)+v\left(\frac{d\zeta}{dx}-\frac{d\xi}{dz}\right)$$
$$+w\left(\frac{d\xi}{dy}-\frac{d\eta}{dx}\right)+\xi\left(\frac{dw}{dy}-\frac{dv}{dz}\right)+\eta\left(\frac{du}{dz}-\frac{dw}{dx}\right)+\zeta\left(\frac{dv}{dx}-\frac{du}{dy}\right)$$
$$=\frac{1}{2}\left(u\Delta^2 u+v\Delta^2 v+w\Delta^2 w\right)+2\Omega^2 \tag{47}$$

Therefore,

$$u\Delta^2 u+v\Delta^2 v+w\Delta^2 w=-2\left(\frac{dA}{dx}+\frac{dB}{dy}+\frac{dC}{dz}\right)-4\Omega^2, \tag{48}$$

and

$$\frac{dK}{dt}=4\mu\iiint\Omega^2 dx\,dy\,dz-2\mu$$
$$\iiint\left(\frac{dA}{dx}+\frac{dB}{dy}+\frac{dC}{dz}\right)dx\,dy\,dz; \tag{49}$$

but we have already reduced the second of these integrals and know that

$$\iiint\left(\frac{dA}{dx}+\frac{dB}{dy}+\frac{dC}{dz}\right)dx\,dy\,dz$$
$$\iint q'\Omega\sin.\theta\sin.\varphi\,d\sigma \tag{50}$$

Consequently

$$\frac{dK}{dt}=4\mu\iiint\Omega^2\,dx\,dy\,dz-2\mu\iint q'\Omega\sin.\theta\sin.\varphi\,d\sigma \tag{51}$$

Comparison of (46) and (61) gives at once

$$\iiint E\,dx\,dy\,dz=4\mu\iint q'\Omega\sin.\theta\sin.\varphi\,d\sigma$$
$$+4\mu\iiint\Omega^2\,dx\,dy\,dz+2\mu\iiint\Delta^2 q\,dx\,dy\,dz \tag{52}$$

For $\theta=o$ or when the direction of motion is along the instantaneous axis of rotatiou we have

$$\frac{dK}{dt}=-4\mu\iiint\Omega^2\,dx\,dy\,dz$$
$$\iiint E\,dx\,dy\,dz=4\mu\iiint\Omega^2\,dx\,dy\,dz+2\mu\iiint\Delta^2 q\,dx\,dy\,dz \tag{53}$$

The same forms are obtained when $\varphi=o$, or when the plane containing the direction of motion and the instantaneous axis of rotation is normal to the surface.

Washington, D.C., Sept. 9th, 1880.

THE STEAM YACHT "ANTHRACITE" AND THE PERKINS SYSTEM OF HIGH PRESSURE STEAM.

By Major GEORGE DEANE.

The little steam yacht *Anthracite,* which has lately visited this continent from England, being the smallest steamer that has ever performed the voyage under steam, crossed the Atlantic from shore to shore in 18 days, on a consumption of 19 tons of coal.

This event has naturally created a great deal of interest with the public generally, as well as with scientific engineers. At the request of friends in Philadelphia, I send the following brief description of the yacht and her machinery to the Committee on Publication of the JOURNAL OF THE FRANKLIN INSTITUTE:

The yacht *Anthracite* was built especially to demonstrate the capabilities of the Perkins system of using steam at higher pressures on an Atlantic voyage, and the more conspicuously to prove the economy of the system it was considered desirable that her tonnage should be as small as possible compatible with the safety of the crew, to which consideration all others had to give place. Her builders, Messrs. Schlesinger & Davis, of Wallsend, Newcastle-on-Tyne, England, were desired to take the New York pilot boats as a guide in laying down the lines for this yacht, and to rig her as a two-masted schooner. Her dimensions are as follows, viz.: Length, 84′ 6″; beam, 16′ 1″; depth, 10′ 2″. The engine and boiler rooms occupy 22′ 6″, and were so constructed to give plenty of space to those interested in watching the working of the machinery, the engine room being furnished with a comfortable settee for the use of those so occupied. Her gross tonnage is 70·26 and registered tonnage 27·91. She has bunkers to carry 16½ tons of coal, and a water tank in the engine room to contain 280 gallons of water. Her crew consists of twelve hands, all told, viz., one captain, one mate, two engineers, two firemen, one steward and cook, and five deck hands. Altogether, she is as well found, handy and safe a sea boat as could be built, and Captain Dent and all her crew speak in the highest terms of her behavior during the very rough and trying weather she had to encounter on her voyage to these shores, as unexpected at the season when she crossed as were the twenty ice-

bergs which were counted from her deck at one and the same time, being, as Captain Dent stated, "the grandest sight of the kind he had ever seen," and he is an old salt and well acquainted with these regions.

The engines of the *Anthracite*, built by Messrs. Hawks, Crawshay & Sons, of Gateshead-upon-Tyne, are constructed on the Perkins system of using steam at higher pressures, and have three cylinders, of 8″, 16″ and 23″ diameter, respectively, with a 15″ stroke. The high pressure and medium cylinders, placed one over the other, are single acting and worked by the same piston rod, the low pressure being double acting. The steam, which first enters the top of the high pressure cylinder, passes into the bottom of the medium cylinder and from thence to the low, is expanded thirty-two times, and is cut off at $\frac{1}{2}$ stroke in the high pressure cylinder and at $\frac{1}{4}$ stroke in the low pressure cylinder. The piston rods are packed with rings made of the Perkins patent metal, requiring no lubrication other than the steam, which it perfectly retains, and thus enables the cylinders to be covered over with a double casing of sheet iron, filled in with a non-conducting material, and so prevents loss of heat.

The Perkins boiler is constructed of a number of wrought iron tubes, which are welded at the ends and placed horizontally over each other, these tubes being connected by smaller tubes. The following are the particulars and dimensions of the boiler of the *Anthracite:* The fire-box is formed of seven rings of tubes. Over the fire-box there are fourteen sections of tubes, each section containing ten tubes, and each tube being 4′ 7″ in length. The internal diameter of these tubes is $2\frac{1}{4}$″ and the external 3″, so that they have a thickness of $\frac{3}{8}$ of an inch, the bursting pressure of which is 20,000 pounds to the square inch. Each section of this boiler was proved to 4000 pounds pressure on the square inch, and the boiler when built up complete was proved to 2500 pounds pressure on the square inch, and this is the test to which all boilers built on the Perkins system are put prior to use, so that such an event as a boiler bursting is next to impossible. The area of the fire-grate is 15 square feet and the total heating surface 633 square feet. The boiler of the *Anthracite* when filled contains about 90 gallons of water. It has been worked at a pressure of 700 pounds to the square inch by the British Admiralty, but the usual pressure employed is from 300 to 500 pounds, and the average pres-

sure being about 350 pounds to the square inch. The boiler is also covered in with a double casing of sheet iron, filled in with a non-conducting material to retain the heat as much as possible, and it was found during a trial test of this machinery lately carried out in England, that a thermometer placed against the boiler casing when the pressure averaged over 350 pounds indicated only 150° Fahr.

As distilled fresh water is used in the boiler the condenser is so constructed that no admixture between the fresh water used in the boiler and the salt water employed in condensing can take place. The distilled water is thus used over and over again, and could all joints and connections be made as practically tight, as they should be theoretically, there would be no loss of water from the escape of steam, etc. As it is, a certain small loss does take place, and this is made good from the tank of fresh water in the engine room, which is distilled before passing into the boiler. All impurities are thus excluded from the water before it enters the boiler, and by the use of the Perkins patent metal for packing the piston rods no lubricant is required in the cylinders, and thus all grease and acids are prevented from coming into contact with the water and so entering the boiler. By this means, also, the preservation and life of the boiler is very much lengthened, and it has been found that the tubes in a boiler which had been at work for fourteen years, when cut open by the English Admiralty, were in as good preservation as when first put to use. Another advantage, especially to yachting men, is that by using this metal the disagreeable smell of burning tallow is got rid of. The metal is made of a compound of tin and copper, and was discovered by Mr. Perkins after many years of experiments with various metals for packing his cylinders so as to effectually retain steam at higher pressures, and is sufficiently hard and flexible to perform the duty required in the cylinders without any other lubricant than the steam, and it has been found that where this metal is used the cylinders and rings get to be as smooth and bright as the face of a looking-glass, thus reducing the friction to a minimum.

Previously to the *Anthracite* leaving England her machinery underwent a trial test, of twelve hours' duration, "of the most rigorous description," by the eminent engineer, Mr. F. J. Bramwell, assisted by the well-known engineer, Mr. Rich, of Eastons & Anderson, and two other engineers. Mr. Bramwell, in his report of this trial, states

"that before comparisons can be properly instituted between the economy of the engines of the *Anthracite* and that of engines of different construction, these engines of different construction should be tried with the same rigor as has characterized the trial of the *Anthracite*." His report contains 128 diagrams, taken during the trial, besides other data, and he gives the consumption of fuel as 1·7 pounds per horse-power per hour for the continuous run, and 1·83 pounds per horse-power per hour *including the coal used in getting up steam*. The report also contains many other points and much information favorable to the Perkins system.

Since the arrival of the *Anthracite* in this country she has been examined and inspected by many of the leading engineers, shipowners, manufacturers, etc., etc., in America, who have taken advantage of the various opportunities given them of observing the working of the machinery during many short trips made for their convenience while the yacht was lying off New York, Philadelphia, Providence, Newport and Watch Hill, Stonington.

Latterly, at the request of the United States Naval authorities, she was for about a fortnight in the hands of the engineers of the Navy Yard at Brooklyn, where a Board of Officers, under Chief Engineer C. H. Loring, U.S.N., and appointed by Mr. Shock, Chief of the Engineering Bureau at Washington, opened up and examined her machinery, and were very much pleased with the appearance of the cylinders and rings after the Atlantic voyage. They also carried out a series of tests and experiments as to the capabilities of the boiler and engines, the consumption of water and coal, etc., etc., taking during the trials about 300 diagrams and other data. To work up all this data and prepare a report will of course take time.

The *Anthracite* has now returned to England, starting from Philadelphia.

It has taken many years to bring the system to its present state of perfection; in fact, it may be said to have taken three generations to do so; for Mr. Jacob Perkins, the grandfather of the present Mr. Loftus Perkins, was working with high pressure steam when he left this country in years gone by to establish a manufactory in England, and to introduce his steam gun, etc. At the present time the system, after many vicissitudes, like most great inventions, is gradually demanding more attention and gaining favor. Also, the good and

economical results obtained from the twenty odd engines now at work on sea and land in the old country prove that it cannot be long before the great economy resulting from thus using high pressure steam will be an acknowledged fact, appealing in the strongest possible manner to the interests of all; for the impossibility of danger arising from the bursting of the boiler will appeal to the interests of the public generally, and the economy of fuel to users of steam.

The voyage of the *Anthracite* to this country, I think, demonstrates fully that the system is quite adapted for use on an Atlantic or other voyage, under any circumstances, for the little steamer got a greater knocking about than would a larger vessel under similar circumstances.

And as to the economy of fuel, Mr. Bramwell's report, and the voyage of the *Anthracite* across from shore to shore in 18 days, burning only 19 tons of coal, and other evidence of the economy of engines working on this system, on land and sea, in England—all point to this claim to economy of fuel and space as a subject well worthy the consideration and inquiry of all manufacturers and shipowners, to whom the expenditure on account of fuel is becoming each day of more and more importance, and the space occupied by such extra fuel of more and more value to the shipowners, meaning as it does the carrying of more paying freight, instead of freight paid for, and to be a charge against the fair profits of the ship.

A matter of great consideration, and which cannot be overlooked in these days of close competition, is the cost of manufacturing the machinery for using steam on the Perkins system; but this is a matter that will soon find a solution among manufacturing engineers, some of whom are already quite prepared to execute any orders that may be given them for the Perkins High Pressure Engine and Boiler on as favorable terms as now demanded for the present engine and boiler. For the rest, supply and demand will rule the question of cost.

There is claimed for this system: 1st, small consumption of fuel; 2d, safety from explosion; 3d, durability of boilers; 4th, disuse of lubricants; 5th, reduction in weight and space—any one of which is an important consideration to steam users.

COAL GAS ENGINEERING.

By Robt. Briggs, C. E.

At the recent meeting of the British Association of Gas Managers a paper* was presented by Mr. T. Travers, of Cork, upon thermal effect of coal gas when employed in heating or cooking, from which the following is extracted. Mr. Travers gives the result of a number of tests made in "a plain, practical method, such as may be applied to the doings of every-day life," that is, tests made without the attempt to obtain exact experimental results, but merely to exhibit the probable heat effect of coal gas for domestic purposes. His preliminary tests were upon the evaporating effect of coal gas of various qualities by means of an apparatus which we are left to suppose was similar to a gas cooking stove, with no attempt to utilize the entire heat of the gases of combustion, which may be assumed to have been allowed to escape in the open air, in the usual way, without condensation of the vapor of water generated by the burning of the hydrogen of the coal gas. "The apparatus employed for producing coal gas was capable of carbonizing 30 cwt. of coal per day," which may be set down as producing 15,000 cubic feet of gas in that time. He consequently had distinctive specimens of gas to test, and Scotch cannel, Newcastle and South Wales coal was experimented with, giving the following results:

Coal.	Illuminating power.	Specific gravity.	Gas consumed in evaporating one imp. gallon of 10 lbs.	Heat used per cu. ft. of gas.
Cannel,	24 candles	.....	18·50 cu. ft.	522
"	22	.....	19·75	490
"	20	.....	20·50	471
Newcastle,	16·5	.....	21·75	444
"	14·5	0·420	22·00	439
"	13·5	.....	22·50	427
South Wales,	10·5	.....	28·00	345
South Wales and 20 p. ct. cannel,	14	.....	23·50	411

* Report of meeting of British Association of Gas Managers, June 8th, 1880 the London *Journal of Gas Lighting.*

In the JOURNAL OF THE FRANKLIN INSTITUTE for April, 1878, will be found a paper by the collator of this article, computing the results of combustion of coal gas,* wherein it was shown that the theoretic heat effect of coal gas of specific gravity = 0·426 was, closely, 622 units where the vapor of water formed in the combustion was permitted to escape uncondensed. [It may be added here that when the vapor is condensed to water at 70° Fahr. the total heat units from 100 pounds of gas coal of the specific gravity of 0·426 are 2,154,350 units, while those from one cubic foot of coal gas at 70° are 690 units, with close approximation.] It follows that about 0·7 of the total heat effect possible (at 622 units) was utilized by Mr. Travers' arrangement from Newcastle coal gas of 0·420 specific gravity.

It will be noticed also that, with the same method of testing, the heat effect increased in some measure with the illuminating power. As the illuminating power increases or diminishes with the quantity of carbon present in "illuminants," and also as the specific gravity, this change can be attributed to the superior ultimate intensity of the carbon flame as compared with the hydrogen flame, an intensity nearly as 3 to 2 in favor of carbon (18293° to 12764°).

Besides these practical tests of different qualities of coal gas, Mr. Travers further instituted a comparison of results from such burners as are found in gas stoves in general, using Newcastle gas coal of 16 candles, as a standard of average gas at present supplied, in all the tests.

	Thermal Units per Cubic Foot of Gas.
No. 1.—Cooking stove fitted with a Bunsen burner formed by a ring of 1¼-inch wrought iron pipe with jet holes 1 inch apart gave .	244
No. 2.—Boiling stove, consisting of single burner, 9 inches diameter, made of ¾-inch pipe, jets ¾ inch apart, . . .	260
No. 3.—Hot-plate, consisting of three rings, each 6 inches diameter, jets ½ inch apart, .	280
No. 4.—Like the above, rings 4 inches diameter, .	310
No. 5.—Cooker, formed of bars of 1-inch wrought iron pipe, jets ½ inch apart, . .	338

* Further extended in the JOURNAL, *vide* April, 1878; June, 1878; Feb., 1879.

	Thermal Units per Cubic Foot of Gas.
No. 6.—Concentric burner, consisting of a double row of rings, one inside the other, 6 inches diameter, ...	390
No. 7.—Burner, same construction as above, but 4 inches diameter, ...	408
No. 8.—Solid flame burner, . .	450
No. 9.—Wallace's burner adapted for domestic purposes, ...	580

The Wallace burner, here referred to, is constructed so that gas jets escape across an aperture like an atomizer, and the mixture of gas and air is more intimately effected than with the other burners.

It being almost certain that in all these instances the combustion was perfect, as the offensive nature of incompletely consumed gas is at once observable, it can be said, on the whole, these tests exhibit the improper control of air supply, or inadequate surface of the vessel receiving heat, or the incomplete contact with that surface, conditions within the province of the gas stove makers to regulate, whence the best ultimate effect to be anticipated from gas stoves is from 0·7 to 0·8 of the theoretic effect —say from 435 to 500 units of heat per cubic foot of gas.

The ordinary economy of coal as fuel in a kitchen range may be taken at 5000 units, the remainder of the heat escaping up the chimney, whence a cubic foot of gas is of equal value to about one-twelfth to one-tenth of a pound of coal. Unfortunately for the coal exhibit in this statement, not one-tenth of the heat given out in the range-fire in any one day is expended in cooking, and it is only in the faculty of warming the room and for heating water that coal demonstrates its economy over coal gas as a fuel.

The foregoing assumption as to comparative value of coal and gas as fuel can be reduced to dollars and cents as follows:

2240 pounds of anthracite coal, at 5000 units = 11,200,000 units, present value $6.00.

3000 cubic feet of gas, at 470 units = 1,410,000 units, present value $6.00.

Ratio of heat value of anthracite coal to that of city coal gas = 7 to 1.

Mr. Travers further describes his experience with burning lumi-

nous flames in the production of heat, giving as an instance the case wherein a stove "from one of the best makers was placed in a low-lying district, and the day pressure was not sufficient, with the result that the Bunsen burner, which formed the heating ring of the stove, frequently fired back." "To increase the pressure was out of the question, and to meet the case, the flame was converted from a non-luminous to a luminous one, of course effectually avoiding the risk of firing back. The consumption of gas was not increased by the alteration, for much of the heat that was before lost by convertion is now converted into radiant heat. Bunsen burners, to be used for heat-giving in fire-places are [says Mr. Travers] to my mind, and for the reasons above given, a mistake; for, unless special arrangements are made, over ninety per cent. passes off in the shape of converted heat."

There exists a common misapprehension of the heat effect of burning a mixture of gas and air, which produces a non-luminous flame as compared with that from the burning of the stream of gas in the ordinary way of lighting. Either of these ways will clearly evolve equal amount of heat from equal quantities of gas perfectly consumed. But the perfect combustion is ensured by the Bunsen arrangement at times and under conditions when it certainly would fail with the common burner. Where the flame of a simple gas jet is brought in contact with any cold body, or cooled by radiation from any cold body near to it, it is likely to be extinguished and to create not only a smoke of unconsumed particles of carbon, but also produce a large proportion of partly burned carbon, or CO, in the gases of combustion. This last product will follow an inadequate supply of air to the gas. Thus a sheet of gas emerging from a horizontal surface of perforated plate or wire gauze will burn with a nearly non-luminous flame, and will emit a large proportion of carbonic oxide in the products of combustion. The heat expended in the production of light is quite unappreciable, as is established fully by the absorption of light generally with inappreciable evolution of heat, and it is seen that the reasons above stated show the only superiority of the Bunsen flame over the luminous one.

Atmospheric Absorption of Ultra Violet Rays.—Cornu has tested various hypotheses with regard to the atmospheric absorption, which lead him to conclude that the absorption is not due, to any extent, either to the vapor of water or to atmospheric duct, but to the material constitution of the gaseous mass of the atmosphere itself.—*Comptes Rendus.* C.

THE PHOTOPHONE.

By Alexander Graham Bell.

Read before the American Association for the Advancement of Science, August, 1880.

In bringing before you some discoveries made by Mr. Sumner Tainter and myself, which have resulted in the construction of apparatus for the production and reproduction of sound by means of light, it is necessary to explain the state of knowledge which formed the starting point of our experiments. I shall first describe the remarkable substance selenium, and the manipulations devised by various experiments; but the final result of our researches has evidenced the the class of substances sensitive to light vibrations until we can propound the fact of such sensitiveness being a general property of all matter. We have found this property in gold, silver, platinum, iron, steel, brass, copper, zinc, lead, antimony, German silver, Jenkins' metal, Babbitt's metal, ivory, celluloid. gutta percha, hard rubber, soft vulcanized rubber, paper, parchment, wood, mica and silvered glass; and the only substances from which we have not obtained results are carbon and thin microscopic glass. We find that when a vibratory beam of light falls upon these substances they emit sounds—the pitch of which depends upon the frequency of the vibratory change in the light. We find farther that, when we control the form or character of the light-vibration on selenium, and probably on the other substances, we control the quality of the sound and obtain all varieties of articulate speech. We can thus, without a conducting wire as in electric telephony, speak from station to station, wherever we can project a beam of light. We have not had opportunity of testing the limit to which this photophonic influence can be extended, but we have spoken to and from points 213 metres apart; and there seems no reason to doubt that the results will be obtained at whatever distance a beam of light can be flashed from one observatory to another. The necessary privacy of our experiments hitherto has alone prevented any attemps at determing the extreme distance at which this new method of vocal communication will be available. I shall now speak of selenium.

In the year 1817 Berzelius and Gottlieb Gahn made an examination of the method of preparing sulphuric acid in use at Gripsholm. Dur-

ing the course of this examination, they observed in the acid a sediment of a partly reddish, partly clear brown color, which, under the action of the blow-pipe, gave out a peculiar odor, like that attributed by Klaproth to tellurium. As tellurium was a substance of extreme rarity, Berzelius attempted its production from this deposit; but he was unable after many experiments, to obtain further indications of its presence. He found plentiful signs of sulphur mixed with mercury, copper, zinc, iron, arsenic and lead, but no trace of tellurium. It was not in the nature of Berzelius to be disheartened by this result. In science every failure advances the boundary of knowledge as well as every success, and Berzelius felt, that if the characteristic odor that had been observed did not proceed from tellurium, it might possibly indicate the presence of some substance then unknown to the chemist. Urged on by this hope he returned with renewed ardor to his work. He collected a great quantity of the material, and submitted the whole mass to various chemical processes. He succeeded in separating successively the sulphur, the mercury, the copper, the tin and the other known substances whose presence had been indicated by his tests—and, after all these had been eliminated, there still remained a residue which proved upon examination to be what he had been in search of—a new elementary substance. The chemical properties of this new element were found to resemble those of tellurium in so remarkable a degree that Berzelius gave to the substance the name of "selenium," from the Greek wore *selene*, the moon—("tellurium," as is well known, being derived from *tellus*, the earth).

Although tellurium and selenium are alike in many respects, they differ in their electrical properties; tellurium being a good conductor of electricity, and selenium, as Berzelius showed, a non-conductor. Knox discovered in 1837, that selenium became a conductor when fused; and Hittorff, in 1852, showed that it conducted, at ordinary temperatures, when in one of its allotropic forms. When selenium is rapidly cooled from a fused condition it is a non-conductor. In this, its vitreous form, it is of a dark-brown color, almost black by reflected light, having an exceedingly brilliant surface. In thin films it is transparent, and appears of a beautiful ruby red by transmitted light. When selenium is cooled from a fused condition with extreme slowness, it presents an entirely different appearance, being of a dull lead color, and having throughout a granulated or crystalline structure, and looking like a metal. In this form it is perfectly opaque to light,

even in very thin films. This variety of selenium has long been known as "granular" or "crystalline" selenium, or, as Regnault called it, "metallic" selenium. It was selenium of this kind that Hittorff found to be a conductor of electricity at ordinary temperatures. He also found that its resistance to the passage of an electrical current diminished continuously by heating up to the point of fusion, and that the resistance suddenly increased in passing from the solid to the liquid condition. It was early discovered that exposure to sunlight hastens the change of selenium from one allotropic form to another; and this observation is significant in the light of recent discoveries.

Although selenium has been known for the last sixty years, it has not yet been utilized to any extent in the arts, and it is still considered simply as a chemical curiosity. It is usually supplied in the form of cylindrical bars. These bars are sometimes found to be in the metallic condition, but more usually they are in the vitreous or non-conducting form. It occurred to Willoughby Smith that on account of the high resistance of crystalline selenium, it might be usefully employed at the short end of a submarine cable in his system of testing and signaling during the process of submersion. Upon experiment the selenium was found to have all the resistance required—some of the bars employed measuring as much as 1,400 megohms—a resistance equivalent to that which would be offered by a telegraph wire long enough to reach from the earth to the sun! But the resistance was found to be extremely variable. Experiments were made to ascertain the cause of this variability. Mr. May, Mr. Willoughby Smith's assistant, discovered that the resistance was less when the selenium was exposed to light than when it was in the dark.

In order to be certain that temperature had nothing to do with the effect, the selenium was placed in a vessel of water, so that the light had to pass through from one to two inches of water in order to reach the selenium. The approach of a lighted candle was found to be sufficient to cause a marked deflection of the needle of the galvanometer connected with the selenium, and the lighting of a piece of magnesium wire caused the selenium to measure less than half the resistance it did the moment before.

These results were naturally at first received by scientific men with some incredulity, but they were verified by Sale, Draper, Moss and others. When selenium is exposed to the action of the solar spectrum the maximum effect is produced, according to Sale, just outside the red

end of the spectrum, in a point nearly coincident with the maximum of the heat rays; but, according to Adams, the maximum effect is produced in the greenish-yellow or most luminous part of the spectrum. Lord Rosse exposed selenium to the action of non-luminous radiations from hot bodies, but could produce no effect; whereas a thermopile under similar circumstances gave abundant indications of a current. He also cut off the heat rays from luminous bodies by the interposition of liquid solutions, such as alum, between the selenium and the source of light, without affecting the power of the light to reduce the resistance of the selenium; whereas the interposition of these same substances almost completely neutralized the effect upon the thermopile. Adams found that selenium was sensitive to the cold light of the moon, and Werner Siemens discovered that, in certain extremely sensitive varieties of selenium, heat and light produced opposite effects. In Siemens' experiments special arrangements were made for the purpose of reducing the resistance of the selenium employed. Two fine platinum wires were coiled together in the shape of a double flat spiral in the zigzag shape, and were laid upon a plate of mica so that the disks did not touch one another. A drop of melted selenium was then placed upon the platinum wire arrangement, and a second sheet of mica was pressed upon the selenium, so as to cause it to spread out and fill the spaces between the wires. Each cell was about the size of a silver dime. The selenium cells were then placed in a paraffine bath and exposed for some hours to a temperature of 210°C., after which they were allowed to cool with extreme slowness. The results obtained with these cells were very extraordinary; in some cases the resistance of the cells, when exposed to light, was only one-fifteenth of their resistance in the dark.

Without dwelling further upon the researches of others, I may say that the chief information concerning the effect of light upon the conductivity of selenium will be found under the names of Willoughby Smith, Lieutenant Sale, Draper and Moss, Professor W. G. Adams, Lord Rosse, Day, Sabini, Dr. Werner Siemens and Dr. C. W. Siemens. All observations by these various authors had been made by means of galvanometers; but it occurred to me that the telephone, from its extreme sensitiveness to electrical influences, might be substituted with advantage. Upon consideration of the subject, however, I saw that the experiments could not be conducted in the ordinary way, for the following reason: The law of audibility of the telephone is

precisely analogous to the law of electric induction. No effect is produced during the passage of a continuous and steady current. It is only at the moment of change from a stronger to a weaker state, or *vice versa*, that any audible effect is produced, and the amount of effect is exactly proportional to the amount of variation in the current. It was, therefore, evident that the telephone could only respond to the effect produced in selenium at the moment of change from light to darkness, or *vice versa;* and that it would be advisable to intermit the light with great rapidity, so as to produce a succession of changes in the conductivity of the selenium, corresponding in frequency to musical vibrations within the limits of the sense of hearing. For I had often noticed that currents of electricity, so feeble as to produce scarcely any audible effects from a telephone when the circuit was simply opened or closed, caused very perceptible musical sounds when the circuit was rapidly interrupted, and that the higher the pitch of sound the more audible was the effect. I was much struck by the idea of producing sound by the action of light in this way. Upon further consideration it appeared to me that all the audible effects obtained from varieties of electricity could also be produced by variations of light acting upon selenium. I saw that the effect could be produced at the extreme distance at which selenium would respond to the action of a luminous body, but that this distance could be indefinitely increased by the use of a parallel beam of light, so that we could telephone from one place to another without the necessity of a conducting wire between the transmitter and receiver. It was evidently necessary, in order to reduce this idea to practice, to devise an apparatus to be operated by the voice of a speaker, by which variations could be produced in a parallel beam of light corresponding to the variations in the air produced by the voice.

I proposed to pass light through a large number of small orifices, which might be of any convenient shape, but were preferably in the form of slits. Two similarly perforated plates were to be employed. One was to be fixed and the other attached to the centre of a diaphragm actuated by the voice, so that the vibration of the diaphragm would cause the movable plate to slide to and fro over the surface of the fixed plate, thus alternately enlarging and contracting the free orifices for the passage of light. In this way the voice of a speaker could control the amount of light passed through the perforated plates without completely obstructing its passage. This apparatus

was to be placed in the path of a parallel beam of light, and the undulatory beam emerging from the apparatus could be received at some distant place upon a lens, or other apparatus, by means of which it could be condensed upon a sensitive piece of selenium placed in a local circuit with a telephone and galvanic battery. The variations in the light produced by the voice of the speaker should cause corresponding variations in the electrical resistance of the selenium employed; and the telephone in circuit with it should reproduce audibly the tones and articulations of the speaker's voice. I obtained some selenium for the purpose of producing the apparatus shown; but found that its resistance was almost infinitely greater than that of any telephone that had been constructed, and I was unable to obtain any audible effects by the action of light. I believed, however, that the obstacle could be overcome by devising mechanical arrangements for reducing the resistance of the selenium, and by constructing special telephones for the purpose. I felt so much confidence in this that, in a lecture delivered before the Royal Institute of Great Britain, upon the 17th of May, 1878, I announced the possibility of hearing a shadow by interrupting the action of light upon selenium. A few days afterward my ideas upon this subject received a fresh impetus by the announcement made by Mr. Willoughby Smith before the Society of Telegraph Engineers that he had heard the action of a ray of light falling upon a bar of crystalline selenium, by listening to a telephone in circuit with it.

It is not unlikely that the publicity given to the speaking telephone during the last few years may have suggested to many minds in different parts of the world somewhat similar ideas to my own.

Although the idea of producing and reproducing sound by the action of light, as described above, was an entirely original and independent conception of my own, I recognize the fact that the knowledge necessary for its conception has been disseminated throughout the civilized world, and that the idea may, therefore, have occurred to many other minds. *The fundamental idea, on which rests the possibility of producing speech by the action of light, is the conception of what may be termed an undulatory beam of light in contradistinction to a merely intermittent one.* By an undulatory beam of light I mean a beam that shines continuously upon the selenium receiver but the intensity of which upon that receiver is subject to rapid changes, corresponding to the changes in the vibratory movement of a particle of air during the transmission of a sound of definite quality through the atmosphere.

The curve that would graphically represent the changes of light would be similar in shape to that representing the movement of the air. I do not know whether this conception had been clearly realized by "J. F. W.," of Kew, or by Mr. Sargent, of Philadelphia, but to Mr. David Brown, of London, is undoubtedly due the honor of having distinctly and independently formulated the conception, and of having devised apparatus—though of a crude nature—for carrying it into execution. It is greatly due to the genius and perseverance of my friend, Mr. Sumner Tainter, of Watertown, Mass., that the problemn of producing and reproducing sound by the agency of light has at last been successfully solved.

The first point to which we devoted our attention was the reduction of the resistance of crystalline selenium within manageable limits. The resistance of selenium cells employed by former experimenters was measured in millions of ohms, and we do not know of any record of a selenium cell measuring less than 250,000 ohms in the dark. *We have succeeded in producing sensitive selenium cells measuring only* 300 *ohms in the dark, and* 155 *ohms in the light.* All former experimenters seemed to have used platinum for the conducting part of their selenium cells, excepting Werner Siemens, who found that iron and copper might be employed. We have also discovered that brass, although chemically acted upon by selenium, forms an excellent and convenient material; indeed, we are inclined to believe that the chemical action between the brass and selenium has contributed to the low resistance of our cells by forming an intimate bond of union between the selenium and brass. We have observed that melted selenium behaves to the other substances as water to a greasy substance, and we are inclined to think that when selenium is used in connection with metals not chemically acted upon by it, the points of contact between selenium and the metal offer a considerable amount of resistance to the passage of a galvanic current. By using brass we have been enabled to construct a large number of selenium cells of different forms. The mode of applying the selenium is as follows: The cell is heated, and when hot enough a stick of selenium is rubbed over the surface. In order to acquire conductivity and sensitiveness, the selenium must next undergo a process of annealing.

We simply heat the selenium over a gas stove and observe its appearance. When the selenium attains a certain temperature, the beautifully reflecting surface becomes dimmed. A cloudiness gradually

extends over it, somewhat like the film of moisture produced by breathing upon a mirror. This appearance gradually increases, and the whole surface is soon seen to be in the metallic granular or crystalline condition. The cell may then be taken off the stove, and cooled in any suitable way. When the heating process is carried too far, the crystalline selenium is seen to melt. Our best results have been obtained by heating the selenium until it crystallizes, and continuing the heating until signs of melting appear, when the gas is immediately put out. The portions that had melted instantly recrystallize, and the selenium is found upon cooling to be a conductor, and to be sensitive to light. The whole operation occupies only a few minutes. This method has not only the advantage of being expeditious, but it proves that many of the accepted theories on this subject are fallacious. Our new method shows that fusion is unnecessary; that conductivity and sensitiveness can be produced without long heating and slow cooling: and that crystallization takes place during the heating process. We have found that on removing the source of heat immediately on the appearance of the cloudiness, distinct and separate crystals can be observed under the microscope, which appear like leaden snow-flakes on a ground of ruby-red. Upon removing the heat, when crystallization is further advanced, we perceive under the microscope masses of these crystals arranged like basaltic columns standing detached from one another; and at a still higher point of heating, the distinct columns are no longer traceable, but the whole mass resembles metallic pudding stone, with here and there a separate snow-flake, like a fossil, on the surface. Selenium crystals formed during slow cooling after fusion present an entirely different appearance, showing distinct facets.

We have devised about fifty forms of apparatus for varying a beam of light in the manner required, but only a few typical varieties need be shown. The source of light may be controlled or a steady beam may be modified at any point in its path. The beam may be controlled in many ways. For instance, it may be polarized and then affected by electrical or magnetic influences in the manner discovered by Faraday and Dr. Ker. The beam of polarized light, instead of being passed through a liquid, may be reflected from the polished pole of an electro-magnet. Another method of affecting a beam of light is to pass it through a lens of variable focus. I observe that a lens of this kind has been invented in France by Dr. Cusco, and is fully described in a recent paper in *La Nature*, but Mr. Tainter and I have used such

a lens in our experiments for months past. The best and simplest form of apparatus for producing the effect remains to be described. This consists of a plane mirror of flexible material—such as silvered mica or microscope glass. Against the back of this mirror the speaker's voice is directed. The light reflected from this mirror is thus thrown into vibrations corresponding to those of the diaphragm itself.

In arranging the apparatus for the purpose of reproducing sound at a distance, any powerful source of light may be used, but we have experimented chiefly with sunlight. For this purpose a large beam is concentrated by means of a lens upon the diaphragm mirror and after reflection is again rendered parallel by means of another lens. The beam is received at a distant station upon a parabolic reflector, in the focus of which is placed a sensitive selenium cell, connected in a local circuit with a battery and telephone. A large number of trials of this apparatus have been made with the transmitting and receiving instruments so far apart that sounds could not be heard directly through the air. In illustration I shall describe one of the most recent of these experiments. Mr. Tainter operated the transmitting instrument, which was placed on the top of the Franklin school-house in Washington, and the sensitive receiver was arranged in one of the windows of my laboratory, 1325 L street, at a distance of 213 metres. Upon placing the telephone to my ear I heard distinctly from the illuminated receiver the words "Mr. Bell, if you hear what I say, come to the window and wave your hat." In laboratory experiments the transmitting and receiving instruments are necessarily within earshot of one another, and we have, therefore, been accustomed to pooling the electric circuit connected with the selenium receiver, so as to place the telephones in another room. By such experiments we have found that articulate speech can be reproduced by the oxyhydrogen light, and even by the light of a kerosene lamp. The loudest effects obtained from light are produced by rapidly interrupting the beam by the perforated disk. The great advantage of this form of apparatus for experimental work is the noiselessness of its rotation, admitting the close approach of the receiver without interfering with the audibility of the effect heard from the latter; for it will be understood that musical tones are emitted from the receiver when no sound is made at the transmitter. A silent motion thus produces a sound. In this way musical tones have been heard even from the light of a candle. When distant effects are sought, another apparatus is used. By placing an opaque screen near

the rotating disk, the beam can be entirely cut off by a slight motion of the hand, and musical signals like the dots and dashes of the Morse telegraph code can thus be produced at the distant receiving station.

We have made experiments with the object of ascertaining the nature of the rays that affect selenium. For this purpose we have placed in the path of an intermittent beam various absorbing substances. Professor Cross has been kind enough to give me his assistance in conducting these experiments. When a solution of alum or bisulphide of carbon is employed, the loudness of the sound produced by the intermittent beam is very slightly diminished; but a solution of iodine in bisulphide of carbon cuts off most, but not all, of the audible effect. Even an apparently opaque sheet of hard rubber does not entirely do this. When the sheet of hard rubber was held near the disk interrupter, the rotation of the disk interrupted what was then an invisible beam, which passed over a space of about twelve feet before it reached the lens, which finally concentrated it upon the selenium cell. A faint but perfectly perceptible musical tone was heard from the telephone connected with the selenium. This could be interrupted at will by placing the hand in the path of the invisible beam. It would be premature, without further experiments, to speculate too much concerning the nature of these invisible rays, but it is difficult to believe that they can be bent rays, as the effect is produced through two sheets of hard rubber containing between them a saturated solution of alum. Although effects are produced as above shown by forms of radiant energy which are invisible, we have named the apparatus for the production and reproduction of sound in this way "The Photophone," because an ordinary beam of light contains the rays which are operative.

It is a well known fact that the molecular disturbance produced in a mass of iron by the magnetizing influence of an intermittent electrical current can be observed as sound by placing the ear in close contact with the iron. It occurred to us that the molecular disturbance produced in crystalline selenium by the action of an intermittent beam of light should be audible in a similar manner without the aid of a telephone or battery. Many experiments were made to verify this theory without definite results. The anomalous behavior of the hard rubber screen suggested the thought of listening to it also. This experiment was tried with extraordinary success. I held the sheet in close contact with my ear, while a beam of intermittent light was

focused upon it by a lens. A distinct musical note was immediately heard. We found the effect intensified by arranging the sheet of hard rubber as a diaphragm, and listening through a hearing tube. We then tried crystalline selenium in the form of a thin disk, and obtained a similar but less intense effect. The other substances which I enumerated at the beginning of my address were now successively tried in the form of thin disks, and sounds were obtained from all but carbon and thin glass. We found hard rubber to produce a louder sound than any other substance we tried, excepting antimony, and paper and mica to produce the weakest sounds. *On the whole, we feel warranted in announcing as our conclusion that sounds can be produced by the action of a variable light from substances of all kinds, when in the form of thin diaphragms.* We have heard from interrupted sunlight very perceptible musical tones through tubes of ordinary vulcanized rubber, of brass, and of wood. These were all the materials at hand in tubular form, and we have had no opportunity since of extending the observations to other substances.

I am extremely glad that I have the opportunity of making the first publication of these researches before a scientific society, for it is from scientific men that my work of the last six years has received its earliest and kindest recognition. I gratefully remember the encouragement which I received from the late Professor Henry at a time when the speaking telephone existed only in theory. Indeed, it is greatly due to the stimulus of his appreciation that the telephone became an accomplished fact. I cannot state too highly also the advantage I received in preliminary experiments on sound vibrations in this building from Professor Cross, and near here from my valued friend Dr. Clarence J. Blake. When the public were incredulous of the possibility of electrical speech, the American Academy of Arts and Sciences, the Philosophical Society of Washington, and the Essex Institute of Salem recognized the reality of the results and honored me by their congratulations. The public interest, I think, was first awakened by the judgment of the very eminent scientific men before whom the telephone was exhibited in Philadelphia, and by the address of Sir William Thomson before the British Association for the Advancement of Science.

At a later period, when even practical telegraphers considered the telephone as a mere scientific toy, Professor John Pierce, Professor Eli W. Blake, Dr. Channing, Mr. Clark and Mr. Jones, of Provi-

dence, R. I., devoted themselves to a series of experiments for the purpose of assisting me in making the telephone of practical utility; and they communicated to me, from time to time, the result of their experiments with a kindness and generosity I can never forget. It is not only pleasant to remember these things and to speak of them, but it is a duty to repeat them, as they give a practical reputation to the often repeated stories of the blindness of scientific men to unaccredited novelties, and of their jealousy of unknown inventors who dare to enter the charmed circle of science. I trust that the scientific favor which was so readily accorded to the telephone may be extended by you to this new claimant, the photophone.

Solidification under Pressure.—Walther Spring has investigated the phenomena of universal regelation, or, in other words, the property which the particles of solid bodies possess of uniting by cohesive action under pressure. The pressure in some of his experiments exceeded 20,000 atmospheres, but in the majority of cases from 2,000 to 3,000 atmospheres were sufficient to secure his results. He concludes that all solid bodies possess the property of uniting when they are in close contact. This property is more or less pronounced in different bodies, and it appears to be a function of the hardness. Soft bodies are easily soldered; hard bodies, with difficulty. There is, however, another element which influences the union, to which he gives the name of waxiness, and which is illustrated by Tresca's experiments upon the flow of solids. In every case the bodies which were submitted to pressure were changed into a denser variety; prismatic sulphur, for example, which has a specific weight of 1·96, was changed into octahedric sulphur, with a specific weight of 2·05. We may infer from this fact that the state which matter assumes depends somewhat upon the volume which it is obliged to occupy, through the action of external forces. These experiments seem calculated to throw new light upon some important geological questions; the layers of primary rocks, for example, may have resulted from the union of the grains of sand or mud which were borne along by the waters; the great pressure would have ground and thrust and broken and soldered them anew so as to give them the form which they now possess; faults and cleavages of every description would be comparable to the crevices of glaciers.—*Bull de l'Acad. Roy. de Belg.* C.

PARAFFINE AS A PROTECTION TO WOOD AND IRON.

By Dr. Eugen Schal.

In chemical technology great difficulties sometimes arise when it is desired to manufacture on a large scale preparations which may be obtained with ease in the laboratory. In most cases the reason of this failure is the fact that in the manufacture the use of glass, porcelain, platinum, etc., which successfully resist the effects of the various chemical agents must be dispensed with, and cheaper and less easily breakable materials, such as iron, copper, lead and wood, substituted. Wood especially cannot be replaced by any other material in the wholesale preparation of muriatic lyes, although the same, according to the strength and temperature of the liquid, undergoes sometimes very rapid destruction.

Dr. Schal says he acquired this experience more particularly in 1874–77, in alizarine manufactories, and that he found in paraffine a means which efficiently protects the wood against damp, acids and alkalis, and by which a great saving is effected. The wooden vessels used, especially tanks of pine wood, for boiling acid and alkaline lyes, as well as casks of oak of the heaviest weights, for separating acid alizarine lyes at a pressure of a half to two atmospheres, were generally totally rotten after a few months, but they lasted for two years when impregnated with paraffine.

Before treating with paraffine, however, the vessels must be thoroughly dried for about three weeks by leaving them in warm and dry air, in order to prepare the wood for the absorption of the paraffine solution in its pores. The latter solution is prepared in the following manner. A part of the paraffine is melted in a spacious metal vessel over a moderate fire, the mass being stirred, the boiler taken from the fire, best moved into the open air, stirred until the mass begins to congeal at the edge, and then about six parts of petroleum, ether, or sulphuret of carbon are poured in, and stirred until solution. The preparation is then put into vessels that may be hermetically closed, or it may be used at once. In preparing the paraffine solution great care must be exercised, as paraffine as well as petroleum ether or sulphuret

of carbon especially are very inflammable, and as even the vapor of the two last mentioned substances, if mixed with air, may give rise to dangerous explosions. Those substances must, therefore, be kept in a cool space, far from light or fire, and well stoppered.

The wood is best saturated in dry and warm weather, as then it dries more quickly, and a smaller quantity of the solving agent is necessary. In winter six parts of the solvent generally do not suffice. This proportion changes with the quality of the paraffine and the temperature; paraffine solving with difficulty is better than the more readily soluble article. Vessels easy of access, such as tanks, tubs, etc., are coated in the open air with the solution as long as the wood will absorb it. The solvents evaporate very quickly, leaving the paraffine behind, so that two or three coatings may be laid on in succession. If the vessel is to be exceptionally well prepared, it is left for a day to dry, and then another layer of the paraffine given.

For vessels in which steam is used for boiling the liquids they contain, he applies after a few days a coating of oil varnish, because the melting point of paraffine is below the boiling point of water, and it is thus in time driven out of the pores by the water.

Instead of oil varnish, the vessels, after being well rubbed down, may also be coated with a thin solution of soluble glass, then dried, and washed with diluted hydrochloric acid. The silicic acid thus formed clogs up the pores from the outside, and provides a protection to the paraffine against the hot water. For vessels which are used only with a moderate heat or cold, the coating of paraffine suffices perfectly. The paraffine is hardly dissolved by diluted cold alcohol, is not poisonous, and may also probably be used with advantage for vessels for keeping liquid. In the case of barrels, the solution was poured in simply after drying them; for an oak barrel holding 9 to 10 hectolitres, one kilo of paraffine dissolved in petroleum ether was required. All openings were then well closed and the barrel rolled about and over for about an hour, so as to bring all parts in contact with the solution. The barrels were finally left standing on their ends for half a day, after which time the remainder not absorbed was emptied, and used for the outside coating. Before applying the solution outside, however, the barrels must be well cleaned, for dirt naturally closes the pores of the wood. As these barrels were very expensive, and had to sustain a pressure of two atmospheres, besides being exposed to a high

temperature, they received on both sides an additional coating of oil varnish. It is, however, necessary to let such a barrel stand in the open air at least a fortnight for drying, and as a precaution fire must be kept away from the barrel while being prepared. As a further precaution, in applying the solution inside, the workman must not be left alone, as it frequently happens that stupefying vapors from the solvent of the paraffine arise, which stupefaction, however, soon disappears in the open air. The oil varnish may also be diluted with petroleum ether, poured into the barrel, and then the latter rolled about, as above described; but many places escape saturation in this operation. After coating with varnish, the barrel is once more dried, and then filled with water, in order to force out the combustible gases.

This is much to be advised, as an explosion once took place in consequence of a workmen trying to enlarge a hole with a red-hot iron, contrary to orders. After the last operation, the inner sides of the various vessels were rubbed down with a dry duster, so as to take off all loose particles.

If impregnation of wood is intended on a large scale, the wood is best stacked in iron boxes, the paraffine solution poured over it, the solution not absorbed drawn off after some time, the solvent forced out of the wood by means of warm air, and recovered by condensation in a cooling apparatus.

If the various manipulations are carefully carried out, the duration of vessels thus prepared is increased from four to six fold, while the outlay is comparatively small leaving out of consideration that the contents of such vessels are frequently lost by the bottom being forced out.

Paraffine, melted with equal parts of linseed oil or rapeseed oil, is also useful for coating iron vessels, which without a substantial preservative are very liable to rust in manufactories of chemicals.

Paraffine likewise protects skin efficiently against wet, alkalis (especially lime), acids, etc.

I have often noticed that workmen in alizarine factories suffered much from sore, ulcerating and swollen hands, especially during winter. After the workmen began to use (twice daily) a solution of paraffine with rapeseed oil and petroleum, chapped hands (not to mention swollen or ulcerated hands) became a scarcity.

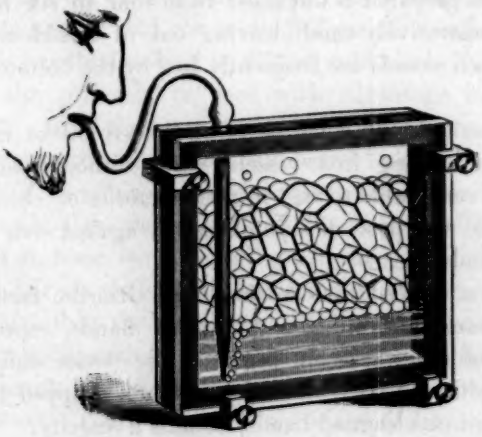
The solution is produced by melting three parts each of paraffine and

rapeseed oil, removing it from the fire, and adding eight parts of petroleum while stirring the mixture. Before using, the solution is stirred a little, and the hands rubbed with it while they are clean and dry. In larger factories, earthenware and tin vessels, filled with this ointment, are placed at convenient spots, and it is believed that the manufacturer as well as the workmen will find this pay.—*Würtembergische Gewerbeblatt.*

HOLMAN'S NEW ILLUSTRATION OF CELL-FORMATION.

By JOHN M. CHILD, A.M.

Mr. D. S. Holman has devised a new illustration of great simplicity and beauty, whereby the method of the formation of cells in vegetable structure may be conveniently shown to an audience. The apparatus consists merely of a tank, which is formed by two pieces of plate-glass, held apart at the bottom and sides by a rubber strip and kept in place by four clamps. In this tank is placed a portion of a soap solution, which is raised in bubbles by a current of air blown into it through a fine glass tube. As the bubbles are formed their tendency to become spheres in virtue of the force of cohesion in their liquid walls is overcome by the capillary attraction of the sides of the tank.



By consequence the films extend across the tank perpendicular to the walls, and the pressure of one bubble upon another causes the forma-

tion of polygonal forms, analogous to those that we see in cross sections of wood fibre. The accompanying figure gives an idea of the appearance that the tank presents when thus filled with bubbles, but does not and cannot portray the beauty of the projection of it which may be made upon a screen. The pencil of rays passing from the condensing lens of a stereopticon is convergent; and as a consequence many rays fall upon the soap films at such a large incident angle that they are almost entirely reflected, and so are tinged with the rich colors resulting from the interference of rays that fall on thin films.

We thus have before us a proof of the tenuity of a layer which is between the limits of $\frac{1}{17000}$ and $\frac{1}{156000}$ of an inch, the latter limit being reached when the color of the film disappears.

The same illustration also affords us an exemplification of the principle, shown in nature in the structure of the honeycomb, that the pressure on each other of equal circles produces a hexagonal structure. Where, in consequence of the regularity of the current of air, we have produced bubbles nearly uniform in size we notice that the polygons formed are six-sided, and that those of a different number of sides exist where there is a diversity in the size of the air-masses.

Friends' Central School, Philadelphia.

Successive Transformations of Photographic Images.—Janssen has reported some additional results of his investigations into the reversals of images by the prolongation or augmentation of luminous energy. He has succeeded in obtaining the following successive transformations: 1. the ordinary negative image; 2. a first neutral state, the plate becoming uniformly obscure under the action of the developer; 3. a positive image which succeeds the first neutral state; 4. a second neutral state, opposed to the first, the plate becoming uniformly clear by the action of the developer; 5. a second negative image, similar to the ordinary negative image, but differing from it by the intermediate states which separate them and by the enormous difference of luminous intensity which is required to obtain it; 6. a third neutral state, in which the second negative image has disappeared and been replaced by a uniform sombre tint. To obtain the second negative image a luminous intensity is required more than a million times as great as that which gives the ordinary negative image.—*Comptes Rendus.* C.

ON THE PROPER FORM OF LIGHTNING CONDUCTORS.

By WILLIAM HENRY PREECE.

Read before the British Association, Aug. 27, 1880.

A lightning conductor erected for the protection of a building consists of a ribbon, rod, chain, rope, or other mass of metal attached to the highest point of the structure, and descending to the earth. What shall be the form of this conductor, has been a vexed question from the days of Franklin to the present. Shall it be dependent on extent of surface or on sectional area? In other words, does the transference of electricity when the potentials are so high as to cause lightning discharges, obey the law of Ohm, or is this law modified by the presence of some fresh condition? Snow Harris was a very warm advocate of the surface form. He used flat ribbons for his ships, and tubes for his buildings. Henry, of Washington, believed in the efficacy of surface. According to him, frictional electricity passes at the surface, galvanic electricity through the mass. M. Melsens is found on the same side, and Guillemin, of Paris, led many French electricians to favor the same view.

On the other hand, Faraday almost angrily espoused the opposite side. "As respects electrical conduction," said he, "no advantage is gained by expanding the rod horizontally into a strap or tube. Surface does nothing; the solid section is the essential element."

The advocates of the solid and cylindrical form argue that the lightning conductor is simply a path by which electricity is transferred from a point of high potential (an electrified cloud) to a point of lower potential (the earth), and that its efficacy depends solely upon its resistance. It obeys the law of Ohm, and its efficacy is therefore for the same material dependent on its mass and sectional area.

The advocates of surface argue, that as in all cases of static charge electricity exists only on the surface, so when electricity of "high tension" is conducted away it is the surface that plays the prime part, and, therefore, the greater the surface the easier the path to the discharge. Again, they say when a cylindrical conductor conveys a charge of electricity it is raised to a "high tension," and is rendered capable of doing mischief; but with the same charge, the greater the surface the

less the density on the surface, and, therefore, the greater the safety. In other words, with a given quantity of electricity, the greater the surface the less the potential. Moreover, they urge, since according to Guillemin currents of electricity flowing in the same direction retard each other with a power varying with the distance separating them, and since a rod may be considered as a bundle of smaller but parallel rods, so a current of electricity may be considered as being made up of many parallel currents, each retarding the other. Hence a ribbon will conduct better than a rod, because the currents are spread further apart, and retard each other less. These arguments have led to the employment of unsightly ribbons and expensive tubes, which have considerably interfered with the establishment of this very necessary element of safety to buildings.

The arguments in favor of the surface form are, in the opinion of the author, deductions from exploded theories, from imperfect experiments, or from erroneous interpretations of well-ascertained facts. No direct experiments have ever been made to solve the question, as far as the author knows. Quantities of electricity, that is, static discharges from condensers, are in incessant use for telegraphic purposes, and are found to follow exactly Ohm's law, even with the most delicate apparatus. The knowledge of the flow of electricity through conductors, of the retarding influence of electro-static capacity upon this flow, and of the distribution of charge, has become so much greater of late years through the great extension of submarine telegraphy and the labors of Sir William Thompson, Clerk-Maxwell and others, that I question if any English electrician would now be found to argue in favor of the surface form. Nevertheless, ribbons and tubes still continue to be used, and it appeared very desirable to settle the question experimentally. I determined to try and do so.

First Experiments, June 28, 1880.—Dr. Warren de la Rue, who is always ready to place his splendidly equipped laboratory at the service of science, not only allowed me to use his enormous battery and his various appliances, but aided me by his advice, and assisted me in conducting the experiments.

Copper conductors, 30 feet long, of precisely the same mass (*a*), drawn into a solid cylinder (*b*) made into a thin tube, and (*c*) rolled into a thin ribbon were first of all obtained. The source of electricity was 3240 chloride of silver cells. The charge was accumulated in a condenser of a capacity of 42·8 microfarads. It was discharged through

platinum wire of ·0125 diameter, of different lengths. The sudden discharge of such a large quantity of electricity as that contained by 42·8 mf. raised to a potential of 3317 (the electro-motive force of the chloride of the silver cell being 1·03 volt) volts is very difficult to measure, it partakes very much of the character of lightning. In fact the difference of potential per unit length of air is probably greater than that of ordinary lightning itself. It completely deflagrates 2½ inches of the platinum wire, but by increasing the length of the wire it could be made to reproduce all the different phases of heat which are indicated by the various shades of red until we reach white heat, fusion, and deflagration. Hence the character of the deflagration, which is faithfully recorded on a white card, to which the wire is attached, by its scattered particles, is a fairly approximate measure of the charge that has passed, while the length of wire, raised to a dull red heat, is a better one, for any variation in the strength of the current within moderate limits is faithfully recorded by the change of color.

Experiment 1.—Similar charges were passed through the ribbon, tube and wire, and in each case 2½ inches of wire were deflagrated. No difference whatever could be detected in the character of the deflagration.

Experiment 2.—Ten inches of wire were taken and similar charges passed through. In each case the wire was raised to very bright redness, bordering on the fusion point, and in two cases the wire broke. In each case the wire knuckled up into wrinkles, and gave evidence of powerful mechanical disturbance. The same wire was not used a second time. No difference could be detected in the effect through the different conductors.

Experiment 3.—Silver wire of the same diameter and length was used, and similar charges transmitted through it. Redness was barely visible, but the behavior of the wire was similar in each case.

The conclusion arrived at unhesitatingly was that change of form produced no difference whatever in the character of the discharge, and that it depended simply on mass.

Second Experiments, July 19, 1880.—As it might be urged that the length of conductor tested was so short, and its resistance so small, that considerable variations might occur and yet be invisible; similar lengths (30 feet) of lead—a very bad conductor, its resistance being twelve times that of copper—were obtained, drawn as a wire, made as a tube, and rolled as a ribbon, each being of similar weight.

Experiment 4.—Charges from the same condenser, 42·8 mf., but with 3280 cells, were passed through, and the discharges observed on 6 inches of platinum wire 0·0125 inches diameter, which in each case was heated to bright redness. No variation whatever could be detected, whether the wire, the tube or the ribbon were used.

Experiment 5.—In order to form some idea as to how closely we could estimate any variation in the character of the discharge, we used a long piece of platinum wire and adjusted the lengths until we obtained just visible redness; then a diminution of 10 per cent. (3 feet) produced a marked change to dull redness, and further excisions raised the temperature to brighter and still brighter red.

The conclusion arrived at was that any change in resistance of 5 per cent. would have been clearly and easily discernible.

It therefore appears proved that the discharges of electricity of high potentials obey the law of Ohm, and are not affected by change of form. Hence, extent of surface does not favor lightning discharges. No more efficient lightning conductor than a cylindrical rod or a wire rope can therefore be devised.

JOSEPH HENRY.

By Prof. A. M. Mayer.

Read before the American Association for the Advancement of Science, August, 1880.

At the meeting of the association in 1878, a committee, composed of Professors Baird, Newcomb and myself, was appointed to prepare a eulogy on our revered and lamented colleague and former president, Joseph Henry. This—I will not say labor, but duty of affection—has devolved on me alone. I would that the other members of this committee had laid before you their tributes to his memory, because for years they had been closely associated with him in his social and professional life in Washington. Yet, while Professor Henry had been the friend of their manhood, he was the friend of my boyhood; and during twenty-five years he ever regarded me—as was his wont to say—with a "paternal interest." To his disinterested kindness and wise counsels is due much, very much, of whatever usefulness there is in me. Hence I have said that it is a duty of affection for me to speak to you about one who was my beloved friend. I shall not,

however, attempt a biography of Joseph Henry, nor will I speak of his administrative life as director of the Smithsonian Institution, for this is known and valued by the whole world. His best eulogy is an account of his discoveries; for a man of science, *as such*, lives in what he has *done*, and not in what he has *said;* nor will he be remembered in what he proposed to do. I will, therefore, with your permission, confine myself chiefly to Henry *as the* discoverer; and I do this the more willingly because I am familiar with his researches, and also because Professor Henry, from time to time, took pleasure in giving me accounts of those mental conceptions which preceded his work, led him to it, and guided him in it. Rightly to appreciate a discoverer we should not look at his work from our time, but go back and regard it from his time; we should not judge his work in the fulness of the light of present knowledge, but in the dim twilight which alone illuminated him to then unknown—but now well known—facts and laws. I will, therefore, endeavor first to present you with a clear, but necessarily very concise, view of the state of our knowledge of electricity when Henry began his original researches in that branch of science, and then point out the value of his discoveries by showing what they added to knowledge, and how they instigated and influenced the discoveries and inventions of other men. Henry began his electrical researches at the age of twenty-eight, in the year 1827, while he was professor of mathematics and natural philosophy in the Albany Academy. At these he continuously worked till 1832, when, at the age of thirty-three, he moved to Princeton College. After a year's break in his work, caused by the preparation of his course of lectures for the college, he is again at original research, and continues his contributions to electrical discoveries till 1842. Thus, during fourteen years, between the ages of twenty-eight and forty-three, he was a constant and fertile worker.

As with many other men of originality, Henry's first essays were in the direction of improving the means of illustrating well-established scientific facts and principles. His first paper, of October, 1827, is interesting because it was his first. In it he improves on the usual apparatus which had been used by Ampère and others to show electrodynamic actions, by employing several turns of insulated wire instead of one, as had previously been the practice. Thus, for example, to show the directive action of the earth's magnetism on a freely moving closed circuit, Henry covered copper wire with silk, and then made

out of it a ring about twenty inches in diameter, formed of several turns of the wire. The extremities of this wire were soldered to zinc and copper plates. The coil was then suspended by silk filaments. On plunging the metal plates into a glass of dilute acid the ring rotated around its point of suspension till its plane took a permanent position at right angles to the magnetic meridian. By a similar arrangement of two concentric coils, one suspended within the other, he neatly showed the mutual actions of voltaic currents flowing in the same or opposite directions, which facts are the foundations of Ampère's celebrated law. We now reach a period when Henry appears as a discoverer, and truly one of no mean order. As I remember his narration to me in the year 1859, it was as follows: He said that one evening he was sitting in his study in Albany with a friend, when, after a few moments of reverie, he arose and exclaimed, "To-morrow I shall make a capital experiment!" For several months he had been brooding over Ampère's electro-dynamic theory of magnetism, and he was then deeply interested in the phenomena of the development of magnetism in soft iron, as shown in the experiments of Arago and Sturgeon. At the moment he had arisen from his chair it had occurred to him that the requirements of the theory of Ampère were not fulfilled in the electro-magnets of Arago and Sturgeon, but that he could get those conditions which the theory required by covering the enveloping wire with a non-conductor like silk, and then wrapping it closely around the soft iron bar in several layers; for the successive layers of wire, coiling first in one direction and then in the other, would tend to produce a resultant action of the current at right angles to the axis of the bar; and furthermore, the great number of convolutions thus obtained would act on a greater number of molecules of the bar, and therefore exalt its magnetism. "When this conception," said Henry, "came into my brain, I was so pleased with it that I could not help rising to my feet and giving it my hearty approbation." Henry did go to work the next day, and, to his great delight and encouragement, discoveries of the highest interest and importance revealed themselves to him week after week. When he had finished his newly conceived magnet he found that it supported several times more weight than did Sturgeon's magnet of equal size and weight. This was his first original discovery.

I will now give, as far as possible, Henry's own words in narrating his subsequent investigations of these very interesting phenomena:

"The maximum effect, however, with this arrangement and a single battery was not yet obtained. After a certain length of wire had been coiled upon the iron the power diminished with a further increase of the number of turns. This was due to the increased resistance which the larger wire offered to the conduction of electricity. Two methods of improvement, therefore, suggested themselves. The first consisted, not in increasing the length of coil, but in using a number of separate coils on the same piece of iron. By this arrangement the resistance to the conduction of the electricity was diminished and a greater quantity made to circulate around the iron from the same battery. The second method of producing a similar result consisted in increasing the number of elements of the battery, or, in other words, the projectile force of the electricity, which enabled it to pass through an increased number of turns of wire, and thus, by increasing the length of the wire, to develop the maximum power of the iron. To test these principles on a larger scale an experimental magnet was constructed. In this a number of compound helices were placed on the same bar, their ends left projecting, and so numbered that they could be all united into one long helix, or variously combined in sets of lesser length. From a series of experiments with this and other magnets it was proved that, in order to produce the greatest amount of magnetism from a battery of a single cup, a number of helices is required; but when a compound battery is used, then one long wire must be employed, making many turns around the iron, the length of wire and consequently the number of turns being commensurate with the projectile power of the battery. In describing the results of my experiments the terms *intensity* and *quantity* magnets were introduced to avoid circumlocution, and were intended to be used merely in a technical sense. By the intensity magnet I designated a piece of soft iron so surrounded with wire that its magnetic power could be called into operation by an intensity battery; and by a quantity magnet a piece of iron so surrounded by a number of separate coils that its magnetism could be fully developed by a quantity battery. "I was," said Henry, "the first to point out this connection of the two kinds of the battery with the two forms of the magnet, in my paper in *Silliman's Journal*, January, 1831, and clearly to state that, when magnetism was to be developed by means of a compound battery, one large coil was to be employed, and when the maximum effect was to be produced by a single battery a number of strands were to be used."

We will now return to Henry's study of the properties of his intensity magnet. This magnet was formed of a piece of iron one-fourth of an inch in diameter, bent in the U form and wound with eight feet of insulated wire. His batteries were two—one formed of a single element with a zinc plate four inches by seven, surrounded by copper and immersed in dilute acid; the other a Cruikshank's battery, or trough, with twenty-five double plates. The plates of this battery were joined in series, and altogether had exactly the same surface of zinc as that in the single-cell battery. The magnet was now connected directly to the single cell. The magnet held up seventy-two ounces. Then five hundred and thirty feet of No. 18 copper wire led the current from the cell to the magnet; it now supported only two ounces. Five hundred and thirty feet more of the wire were introduced into the circuit, and then the magnet held but one ounce. In these facts Henry faced the same results as confronted Barlow five years before, and caused Barlow then to say: "In a very early stage of electro-magnetic experiments it had been suggested [by Laplace, Ampère and others] that an instantaneous telegraph might be established by means of conducting wires and compasses, but I found such a sensible diminution with only two hundred feet of wire, as at once to convince me of the impracticability of the scheme"; and such, at that day, seemed to be the common opinion of men of science. But this opinion is presently to be shown by Henry to be ill-founded, by reason of the ignorance of the relations which have of necessity to exist between the kind of battery and the kind of magnet in order to produce electro-magnetic action at a distance—relations which Henry was the first to discover. This accomplishment justly entitles him to be regarded as a man of genius and a discoverer of no mean order. This discovery will always remain the one important fact that was to be known, to be understood and to be applied, before it was possible to have constructed any form of electro-magnetic telegraph. Let us see how Henry made this discovery.

After ending the experiments with the one-cell battery and reaching results which seemed to confirm the opinion of Barlow as to the "impracticability of the scheme" of an electro-magnetic telegraph, Henry attached his magnet to the second battery, formed of twenty-five cells, arranged in series. The current from this battery was sent to the magnet through one thousand and sixty feet of the same wire as had been used in the experiments with the first battery of one cell.

The magnet now lifted eight ounces. It had held up only one ounce, when with the same length of interposed wire the battery of one cell was used. He now attached his electro-magnet directly to the poles of the twenty-five cell battery, when, to his astonishment, it only held seven ounces. The same magnet, it will be remembered, when attached to the one-cell battery, supported seventy-two ounces. Here were facts of the highest significance, and Henry was not slow to seize them in all their bearings. Referring to these experiments, he said, in 1857: "These steps in the advance of electro-magnetism, though small, were such as to interest and astonish the scientific world. These developments were considered at the time of much importance in a scientific point of view, and they subsequently furnished the means by which magneto-electricity, the phenomena of diamagnetism, and the magnetic effects in polarized light were discovered. They gave rise to the various forms of electro-magnetic machines which have exercised the ingenuity of inventors in every part of the world, and were of immediate applicability in the introduction of the magnet to telegraphic purposes. Neither the electro-magnet of Sturgeon nor any electro-magnet ever made previous to my investigations was applicable to transmitting power to a distance."

Not satisfied with the mere statement that his discovery was "directly applicable to Mr. Barlow's project of forming an electro-magnetic telegraph," he actually constructed one, some time during the year 1831, around one of the upper rooms of the Albany Academy. It was more than a mile in length, and made signals by sounding a bell. This was the first electro-magnetic telegraph which had worked through so great a length of wire. It was the first "sounding" electro-magnetic telegraph. The relative parts played by Henry and Morse are described in Henry's "statement" published by the Smithsonian in 1857. "*The principles*," says Henry, "*I had developed were applied by Dr. Gale to render Morse's machine effective at a distance.*" This statement seems to be as direct, as clear, as truthful and as comprehensive as one can desire. I will take the liberty of remarking that had Henry taken out a patent in which he claimed as his invention an electro-magnet formed of two or more layers of insulated wire, Morse's patent would not have been so valuable. Remember, I speak not of the merit of the invention, but of the merit of the patent; for the invention, so far as Morse is concerned, would have

remained the same, because one essential part of a Morse telegraph is Henry's intensity magnet, and certainly Morse never invented that.

If Ohm's law had been known to Henry, with all of its consequences, when applied to his discovery of the exaltation of the electro-magnetism of iron, in connection with his discovery of the proper relations necessary between batteries and magnet to get the greatest electro-magnetic effects, his discoveries would appear dwarfed, though yet of excellent workmanship. But did he at this time, 1827 to 1832, know of Ohm's law? I infer that Henry arrived at his discoveries independently of such knowledge, and for twofold reasons. First, Ohm's law was published as late as 1827, in Berlin, and was received almost contemptuously. Henry was unable to read German, and Ohm's papers were first published in English in 1841. Secondly, from the manner in which Henry worked at his problems and viewed his results, I conclude that he had no knowledge of Ohm's laws; else why should he have been astonished at the effects when his intensity magnet was connected with his intensity battery? Henry, now in possession of powerful magnets, began to work on another problem. He tried to do the reverse of what he had already done. His magnet was made by the action of the electric current, and he now tried to obtain an electric current from the magnet, and he succeeded. Henry and Faraday independently discovered the means of producing an electric current and spark from a magnet. Tyndall speaks of this experimental result as "the Mont Blanc of Faraday's own achievements." A few words now will place Henry in his proper and just relations to these important discoveries. All the information he had received from Faraday's discovery was the account of Farraday's production of magneto-electricity by the sudden insertion of a magnet into a helix and its sudden withdrawal therefrom. Henry's experiment is entirely different, and certainly was entirely original with him; but it is essentially identical with another of Faraday's of which Henry had no knowledge. Thus it appears that, although Henry cannot be placed on record as the *first* discoverer of the magneto-electric current, he stands alone as its *second* independent discoverer.

Henry's next discovery was that of the induction of a current upon itself, or of the extra current, as it is sometimes called. Here he anticipated Faraday by nearly two years and a half in the observation of the fundamental facts. Notwithstanding an explicit disclaimer of Faraday, the credit of this discovery has been generally given to the

latter. This is accounted for by the fact that, although Henry anticipated others in his observations, he had not leisure to follow them up to their full explanation until after Faraday had completely unraveled their nature. In 1838, after his return from a first visit to Europe, Henry discovered an entirely new class of phenomena in electrical induction. He first showed that an induced current may excite a second induced current in a neighboring closed conductor, that this last may induce a third current, and so on. These currents Henry styled currents of the first, second, third, etc., orders, and he showed that they alternate in their direction successively. He investigates the differences in these currents as they flow through different resistances. The same phenomena he tracks through the inductive sections of the discharge of the Leyden jar and of the frictional electrical machine, and shows how they differ from those produced by the voltaic battery. These researches are the most finished of Henry's investigations, and will ever be regarded as models of careful and thorough scientific work.

Henry had a versatile mind, and did not confine his attention to the study of electricity. His researches in molecular physics, though not extensive, are remarkable. Here his suggestions and methods have stimulated others to follow in the paths which he has pointed out. In 1839 Henry made a curious discovery as to the permeability of lead to mercury. He found mercury would even ascend a lead wire to the height of a yard in a few days. He even made what might be called siphons of lead, which would nearly empty a vessel of mercury by drawing the fluid over its sides. Subsequently, in 1845, with Mr. Cornelius, he proved that copper, when heated to the melting point of silver, would absorb the latter metal. In 1844 Henry was investigating the nature of the forces acting in liquid films. Studying the tenacity of the soap bubble film, although his experiments could only furnish approximate results, they showed that the molecular attraction of water for water is really several hundred pounds to the square inch, and probably equal to the attraction of ice for ice. Another of Henry's investigations, having a practical bearing, should be more widely known than it is. Among his duties as chairman of the United States Lighthouse Board was the testing of the various physical properties of the oils submitted to the government for purchase. Fluidity was one of these properties for which it seemed most difficult to get reliable tests. Here he very ingeniously applied the theorem of Torri-

celli, which shows that equal quantities of all liquids of equal fluidity will flow out of an orifice in equal times. Henry found that with different oils the flow of equal quantities differed, the rapidity of flow of sperm oil exceeding that of lard oil in the ratio of 100 to 167. Alcohol proved to be less fluid than water. Henry took a deep interest in acoustics. His additions to this science were chiefly the results of experiments upon fog signals. He made extensive experiments with various sound producing instruments, and eventually decided in favor of the steam siren fog horn. He determined that these instruments send their sound farthest when tuned very near to the treble C, and he also showed the uselessness of applying reflectors to them. During eleven years Henry sought to advance the efficiency of our fog signals by experiments in all weathers. Many very puzzling facts were collected. Thus it was observed that a sound coming to a mariner against the wind would cease to be audible on the deck of his vessel while it continued to be heard at the masthead. It was also observed that upon approaching a fog horn from a distance the intensity of sound would gradually increase, then die down rapidly, become inaudible through a space of three or four miles, and perhaps not reappear until the vessel was within a mile of the instrument. These facts demanded explanation, and for a long time remained enigmas to Henry; till one day he met with a paper by Professor Stokes, in which the effect of an upper current in deflecting a wave of sound is fully explained. This hypothesis of Stokes Henry was able to apply to the solution of the problems in question.

Henry's services to the Lighthouse Board were of great value to the country. The fact that his investigations showed that lard oil heated to about 250° Fahr. is superior in fluidity and illuminating power to sperm oil caused the substitution of the former for the latter. A dollar a gallon was saved, which amounts to about one hundred thousand dollars a year in favor of the government. In light and heat Henry made several investigations which we must pass over. One, however, is so important that it cannot be omitted. I refer to his application of the thermopile to determining the distribution of heat on the optical images of distant objects. In a bold and wonderful experiment he sought to study the distribution of heat on the surface of the sun. In 1845, with Stephen Alexander, he formed an image of the sun, by means of a telescope, upon a screen. In this screen was cut an aperture, closed by the surface of a thermopile. By

a motion of the telescope any part of the image could be brought upon the pile. A solar spot being present, he clearly proved that it emitted less heat than the surrounding parts of the luminous disk. This method of research was shown to Secchi. On his return to Europe the latter made no small repute by extending these observations, using Henry's methods, but often, I fear, not giving full credit to the originator. But let that pass, for the bread which Henry cast upon the waters has returned to our own shores, thanks to the genius of our colleague Langley.

It is impossible to crowd into one brief hour the thoughts which were his occupation during more than half a century. I have at least endeavored to exhibit the more important of the labors of his life. What shall we think of them? Surely they are on as high a plane as those of any of his contemporaries, and show as much originality as theirs in their conception—as much skill in their execution. Yet it has been said that Henry was not a man of genius. As I have not been able to find that the philosophers, who have the special charge of giving from time to time definitions of genius, have been able to come to any satisfactory conclusion among themselves, I will leave their company, and, with your liberty, take my definition from a book which, if we accredit Thackeray, is one of the very best, if not the best, novel ever writ in English. After listening to this I will allow you to form your own opinion as to whether Henry did or did not possess genius. "By genius I would understand that power, or rather those powers of the mind which are capable of penetrating into all things within our reach and knowledge, and of distinguishing their essential differences. These are no other than invention and judgment, and they are both called by the collective name of genius, as they are of those gifts of nature which we bring with us into the world. Concerning each of which, many seem to have fallen into very great errors; for by invention, I believe, is generally understood a creative faculty, which would indeed prove most romance writers to have the highest pretensions to it; whereas by invention is meant no more, and the word so signifies, than discovery in finding out; or, to explain it at large, a quick and sagacious penetration into the true essence of all the objects of our contemplation. This, I think, can rarely exist without the concomitancy of judgment, for how can we be said to have discovered the true essence of two things, without discovering their difference seems to me hard to conceive. Now this last is the undis-

puted province of judgment; and yet some few men of wit have agreed with all the dull fellows in the world in representing these two to have been seldom or never the property of one and the same person." My own judgment, if of any value, would rank the ability of Henry—I do not say his achievements—a little below that of Faraday. Indeed, their lives and their manners of working were strangely alike. Faraday was the son of a blacksmith. He once wrote: "I love a smith's shop and anything relating to smithery. My father was a smith." Henry's father plied a schooner on the Hudson. Each started in life with moral and benevolent habits, well developed and healthy bodies, quick and accurate perceptions, calm judgment and self-reliance, tempered with morality and good manners—a good ground, surely, in which to plant the germs of the scientific life. Faraday was an apprentice to a bookbinder. Henry served in the same capacity under a silversmith. Each, endowed with a lively imagination, was in his younger days fond of romance and the drama; and, by a singular similarity of accidents, each had his attention turned to science by a book which chance threw in his way. This work in the case of Faraday was *Mrs. Marcet's Conversations on Chemistry*, and the book which influenced Henry's career was *Gregory's Lectures on Experimental Philosophy, Astronomy and Chemistry.* Of Mrs. Marcet's book Faraday thus writes: "My dear Friend—Your subject interested me deeply every way; for Mrs. Marcet was a good friend to me, as she must have been to many of the human race. I entered the shop of a bookseller and bookbinder at the age of thirteen, in the year 1804, remaining there eight years, and during the chief part of the time bound books. Now, it was in those books, in the hours of the week, that I found the beginning of my philosophy. There were two that especially helped me—the *Encyclopædia Britannica*, from which I gained my first notions of electricity, and Mrs. Marcet's *Conversations on Chemistry*, which gave me my foundation in that science. Do not suppose that I was a very deep thinker, or was marked a precocious person. I was a burly, imaginative person, and could believe in the *Arabian Nights* as easily as in the *Encyclopædia*. But facts were important to me and saved me. I could trust a fact, and always cross-examined an assertion. So when I questioned Mrs. Marcet's book by such little experiments as I could find means to perform, and found it true to the facts as I could understand them, I felt that I had got hold of an anchor in chemical knowledge, and clung fast to it.

Thence my deep veneration for Mrs. Marcet—first as one who had conferred great personal good pleasure on me, and then as one able to convey the truth and principle of those boundless fields of knowledge which concern natural things to the young, untaught and inquiring mind. You may imagine my delight when I came to know Mrs. Marcet personally; now often I cast my thoughts backward, delighting to connect the past and the present; how often, when sending a paper to her as a thank offering, I thought of my first instructress, and such thoughts will remain with me."

Henry wrote on the inside of the cover of Gregory's work the following words: "This book, although by no means a profound work, has, under Providence, exerted a remarkable influence on my life. It accidentally fell into my hands when I was about sixteen years old, and was the first book I ever read with attention. It opened to me a new world of thought and enjoyment; invested things before almost unnoticed with the highest interest, fixed my mind on the study of nature, and caused me to resolve at the time of reading it that I would immediately begin to devote my life to the acquisition of knowledge —J. H." Each of these philosophers worked with simple instruments, mostly constructed by his own hands, and by methods so direct that he appeared to have an almost intuitive perception into the workings of nature; and each gave great care to the composition of his writings, sending his discoveries into the world clothed in simple and elegant English. Finally, each loved science more than money, and his Creator more than either. There was sympathy between these men, and Henry loved to dwell on the hours that he and Bache spent in Faraday's society. I shall never forget Henry's account of his visit to King's College, London, where Faraday, Wheatstone, Daniell and he had met to try and evolve the electric spark from the thermopile. Each in turn attempted and failed. Then came Henry's turn. He succeeded, calling in the aid of his discovery of the effect of a long interpolar wire wrapped around a piece of soft iron. Faraday became as wild as a boy, and, jumping up, shouted, "Hurrah for the Yankee experiment." And Faraday and Wheatstone reciprocated the high estimation in which Henry held them. During a visit to England, not long before Wheatstone's death, he told me that Faraday and he had, after Henry's classical investigation of the induced currents of different orders, written a joint letter to the council of the Royal Society, urging that the Copley medal, "that laurel wreath of science,"

should be bestowed on Henry. On further consultation with members of the council it was decided to defer the honor till it would come with greater *éclat*, when Henry had continued farther his researches in electricity. Henry's removal to Washington interrupted these investigations. Wheatstone promised to give me this letter to convey to Henry as an evidence of the high appreciation which Faraday and he had for Henry's genius, but Wheatstone's untimely death prevented this. Both Faraday and he gave much thought to the philosophy of education, and in the main their ideas agreed. I may in this connection be excused from reading abstracts from a letter from Henry soon after he had received the news that I had given my son his name. After a playful discussion of the name Joseph, Jo and Josey, he says—what may be news to most of you: "I did not object to Henry as a first name, although I have been sorry that my grandfather, in coming from Scotland to this country, substituted it for Hendrie, a much less common, and therefore, distinctive name." He then proceeds: "I hope that both his body and mind will be developed by proper training and instruction, that he may become an efficient, wise and good man. I say efficient and wise, because these two characteristics are not always united in the same person. Indeed, most of the inefficiency of the world is due to their separation. Wisdom may know what ought to be done, but it requires the aid of efficiency to accomplish the desired object. I hope that in the education of your son due attention may not only be given to the proper development of both these faculties, but also they will be cultivated in the order of nature; that is, doing before thinking, art before science. By inverting this order much injury is frequently done to a child, especially in the case of the only son of a widowed mother, in which a precocious boy becomes an insignificant man. On examination in such a case it will generally be found that the boy has never been drilled into expertness in the art of language, of arithmetic, or of spelling, of attention, perseverance and order, or, in other words, of the habits of an active and efficient life."

Henry was a man of extensive reading, and often surprised his friends by the extent and accuracy of his information, and by the original manner in which he brought his knowledge before them. Not only was he well versed in those subjects in which one might naturally suppose him proficient, but in departments of knowledge entirely distinct from that in which he gained his reputation as an original

thinker. Although without a musical ear he had a nice feeling for the movement of a poem, and was fond of drawing from his retentive memory poetic quotations apt to the occasion. He was a diligent student of mental philosophy, and also took a lively interest in the progress of biographical science, especially in following the recent generalization of Darwin; while the astonishing development of modern research in tracking the history of prehistoric man had for him a peculiar fascination. Yet with all his learning, reputation and influence, Henry was as modest as he was pure. One day, on opening Henry's copy of *Young's Lectures on Natural Philosophy*, a book which he has studied more than any other work of science, I read on the fly-leaf, written in his own hand, these words:

> "In Nature's infinite book of secrecy
> A little I can read."—*Shakespeare.*

And did he not read a little "in Nature's infinite book of secrecy"? And did he not read that little well? May we all read our little in that book as modestly and as reverently as did Joseph Henry.

WOODBURY-TYPE PHOTO-PLATES — THE OLD AND NEW PROCESS.

We must congratulate Mr. Woodbury upon the success which has rewarded his efforts to reduce photo-relief printing to a simple form. As the method at present stands, with the last finishing touch that has just been given to it, no process of photo-engraving could be more easy or practical. Within a twelvemonth, Woodbury-type has not only become untrammeled by patent, but robbed of every complication that stood in the way of vulgarizing the process. We shall not be surprised, after this, if, when another year has passed, many photographers—or, at any rate, those in the first rank—take to producing their pictures by mechanical means instead of by sunlight, and exchange the frame for the press in their printing department. Already we hear of several Paris houses that have taken up photo-relief printing, while far-off Madrid, it is said, has sent representatives to the French capital to learn if the good news be true.

The lapse of the Woodbury-type patent in England caused several in this country to take up photo-relief printing. Besides those directly interested in the patent may be mentioned the Autotype Company and

the London Stereoscopic Company as among the first to recognize the the value of the process. We all of us know the orthodox method of proceeding. A gelatine pellicle, slightly tinted, but still transparent, was sensitized in a solution of bichromate, and, after drying, exposed under a negative. The surface thus reprinted having been rendered partially insoluble—where the light had got to it through the negative—was then washed in lukewarm water, the result, of course, being an intaglio, or image represented by hollows, more or less deep. This intaglio or mould, when dried and hardened, was put at the bottom of a shallow steel tray, the walls of which were knife edges; a sheet of lead was placed upon the mould, and the whole put under a hydraulic press. Enormous pressure was necessary. In the case of a carte-de-visite picture a pressure of something like 150 tons was required, while in the case of a picture measuring eight or ten inches, no less than a strain of 500 tons was deemed requisite to force the lead into the cavities of the gelatine image. The knife edges cut through the lead, and thus allowed the latter to fill up the tray precisely, a measure indispensable to prevent injury to the gelatine mould.

In this way, then, the engraving plate that served for the printing off of Woodbury-type impressions was made. Not only are the operations very delicate and nice in their nature, but they involve much time and costly apparatus. The mere fact that a hydraulic press, capable of exerting a pressure of from 150 to 500 tons, is a necessity, was of itself sufficient to prevent Woodbury-type being worked by photographers at large, and it was for this reason why only large firms could afford to practice the process. Now Mr. Woodbury shows us how press, steel tray, lead, and hydraulic machinery may be dispensed with altogether, and any photographer, who possesses a rolling press and a supply of tin foil can prepare a properly engraved plate. The modification is so simple that it seems absurd the plan was not thought of before. Mr. Woodbury takes a positive instead of a negative to begin with, and with this produces his gelatine mould. This mould is hardened as before, attached the while to a surface of patent plate, so that its level character may be depended upon. As soon as dry, a sheet of tin foil is placed upon the gelatine mould, and, to force the tin metal securely into every crevice, mould and tin foil are sent through an ordinary rolling press. This is all. The gelatine mould with its lining of lead—for tin foil, as our readers very well know, is simply sheet lead—serves for printing off the Woodbury pictures, and to

judge from the appearance of the prints with which Mr. Woodbury has favored us, the impressions are equal in every respect to those furnished by moulds in which the lead is solid.

Of course there is the making of the gelatine mould in the first place, and the actual printing off of the impressions in the last, and to do these operations well and successfully, some apparatus and some experience are necessary. The experience can obviously only be acquired by practice, but we have no doubt that Mr. Woodbury will see his way to giving instructions as to apparatus and manipulations to British photographers in the same manner as he affords assistance to those abroad. Mr. Woodbury, we believe, is bound by some engagement or agreement not to do any teaching in the matter of photo-relief printing in this country, and hence it is that the important improvements he has recently made known come to us from abroad. The business arrangements between Mr. Woodbury and his co-operators do not, however, concern us, and our duty here is but to chronicle the simple and easy stage to which the photo-relief printing has now been brought.—*Photographic News.*

A NEW POWERFUL AND CONSTANT BATTERY WITHOUT ACID.

By Emile Reynier.

The problem of the abundant and economical production of electricity in the arts has been solved in a satisfactory manner by magneto-electric machines; but in establishments where motive power cannot be obtained, and which are very numerous, recourse must be had to nitric acid batteries, the inconveniences of which are well known.

Many persons have endeavored to obtain batteries which are both powerful and constant, and which at the same time do not give off disagreeable fumes. Up to the present no batteries have fulfilled all these conditions, and the Grove and Bunsen couples have continued to be employed in spite of the disagreeable and hurtful fumes which they give off, and in spite of their expensive nature and the trouble they give in requiring to have their zincs amalgamated, their contacts cleaned, etc., operations which must be repeated each time the battery is set up.

I have tried, amongst many other things, to get rid of these inconveniences, and to a very great extent have succeeded by means of my new battery, of which the following is an account.

The zinc of this new battery is plunged into a solution of caustic soda, the negative electrode, which is of copper, is depolarized by a solution of sulphate of copper, separated from the alkaline solution by a porous cell. The couple thus arranged is constant. Its electro-motive force is considerable, being from 1·3 to 1·5 volts, according to the degree of concentration of the solutions.

The solutions of soda and sulphate of copper have a medium conductivity; I have diminished their resistance by the addition of certain selected salts. On the other hand, I have notably reduced the resistance of the porous chamber by employing for that purpose parchment paper, which has already been employed for the same object by M. F. Carré.

I superpose several leaves of this paper in order to reduce the permeability, and I make my porous vessels in the form of a flat rectangular prism, so that relatively large surfaces can be given to the electrodes.

These prismatic vessels are obtained without cementing or a joint by the following method: in the middle of the leaf of parchment paper of which the vessel is to be constructed the base of the prism is sketched; on each of the sides of this polygon, and at a distance equal to the height of the vessel, parallel lines are traced, which together form a polygon larger than the one cut out. Finally, the vessel is formed by folding the portions of the septum placed outside the geometrical development of the prism. These folds are folded close one over the other, so that those faces of the vessel are made least permeable which are so required.

The zinc and the copper of the battery are cut out, without waste of the metal, from the ordinary commercial sheet zinc; the connecting lugs are formed out of the piece itself, which offers the double advantage of no soldering being required and of a passage for the circulation of the liquid being given. The copper is placed outside the porous vessel.

The initial electro-motive force of the ordinary zinc and copper couple, immersed in my solutions, is 1·47 volts. It falls to 1·35 volts after being on short circuit continually. The resistance is ·075 ohms

for the pattern here represented, the height of which is ·20 metres, and the capacity 3 litres.

In order to determine the rank which this battery should occupy in the series of couples with which it was compared, I have drawn up a list showing for each their electro-motive force, *E*, their internal resistance, *R*, and the *outside work done*, *T*, expressed in kilogrammes per second, this latter value being calculated by the expression:

$$T = \frac{E^2}{4R \times 9{\cdot}81}$$

By dividing the values in kilogramme metres by the mechanical equivalent of heat, the values of the work done can be obtained in calorics (gramme degrees), which values are also given in the following table:

Name of Battery.	Constants.		Work.	
	E. In volts.	*R.* In ohms.	*T.* In kilometres.	*T.* In calorics.
Bunsen: ordinary form; height, 20 metres, ...	1·80	·24	·344	·796
Bunsen: Ruhmkorff pattern; height, 20 metres, . .	1·80	·06	1·378	3·189
Daniell: round form; height 20 metres, ...	1·06	2·80	·010	·023
Daniell: Thomson's tray form; electrodes 12 decimetres sq.,	1·06	·20	·143	·331
Daniell: Carré pattern; height, 60 metres, ...	1·06	·12	·238	·551
Reynier: rectangular form; height, 20 metres, . .	1·35	·075	·619	1·440

It can be seen that my new rectangular couple, 20 metres in height, surpasses in power the largest sulphate of copper and sulphate of zinc batteries; it is about twice as powerful as the ordinary round Bunsen, and is only exceeded by the rectangular Bunsen, Ruhmkorff pattern. The zinc is not amalgamated, nevertheless it is not attacked on open circuit by the alkaline liquid in which it is immersed; consequently the weight of zinc consumed is perfectly proportional to the work done, and gives exactly the quantity of current generated.

The new battery, as has been before stated, does not emit any fumes, consequently it contains after work all the substances employed, altered in nature, but without loss. It is possible, therefore, to regenerate these products, that is to say, to bring them back again almost to their

original state. In order to do this, the exhausted liquids must be traversed by a quantity of electricity rather greater than that given out by the pile, by dissolving the copper deposited and depositing the zinc dissolved.

If magneto-electric machines are used for producing the electricity necessary to renew the battery, the renewal is done at the expense of motive power. Economically produced by the aid of powerful machines, the electricity becomes stored up in the liquids, regenerated to the state of energy which is disposable and portable. This indirect transport of electricity generated by machines would be, in most cases, more practicable and more advantageous than the direct transmission by cables.

Actually the renewed liquids are not employed, the new battery offering as it does a notable economy of material and labor over the nitric acid couples. As to the industrial realization of the process of regeneration, which should render my battery economically applicable to small electric motors and to domestic lighting, it is yet hindered by certain difficulties foreign to the art, which will, I trust, be overcome eventually.—*La Lumière Electrique.*

THE TEMPERATURE OF FLAMES.

From the paper of F. Rosetti,* in the *Annales de Chimie et de Physique*, we collate that his deductions from experiments with flames emitted by the ordinary gas burner, the Bunsen burner and the electric light, by means of a thermo-pile and a delicate reflecting galvanometer, gave the following results:

With the temperature of the air at 59° Fahr. (= 15°C.) the ultimate temperature of the blue flame at the outer edge of surface of a fantail burner was 2370° Fahr., while that of the interior white flame was 2100° Fahr. The average temperature of the flame he establishes at 2170° Fahr. It will be seen by referring to the article on Gas Engineering which was published in the JOURNAL OF THE FRANKLIN INSTITUTE in April, 1878, that the ultimate temperature of coal gas (based on the theoretic heat value of its constituents), when the products of combustion are taken to include the volume of air

* *Annales de Chimie et de Physique*, 5th series, vol. xviii, p. 457.

needed to effect complete combustion, is 2641° when the gas and air for combustion were taken at 70°.

The ultimate temperature of the flame of a Bunsen burner is given at 2280° Fahr.

The electric light gives as a maximum intensity of heat:

For the positive pole = 7050° Fahr.,
For the negative pole = 5700° Fahr. and
For the arc itself = 8700° Fahr.

There is still wanting an accurate measure of the *quantity* of heat emitted by the electric light to compare with the heat equivalent of the electro-motive force expended in the arc, and thus to eliminate the expenditure of heat in the production of light. B.

Book Notices.

AN ELEMENTARY TREATISE ON ELECTRIC BATTERIES, from the French of Alfred Niaudet, translated by L. M. Fishback. 12mo. New York: John Wiley & Sons. 1880.

It is gratifying to examine a complete, thorough and yet pleasantly written and easily comprehensible text book, and this little treatise presents many qualities to entitle it to be considered a model of its kind. Its marked excellence is derived from the possession of full knowledge of the history and practice of the use of batteries by the author, beside that happy instructive ability which allows him to impart his information in fluent rather than precise language, suited to the casual and not alone the exact student. It is a recommendation that the treatise is divested from all consideration of electricity or electric force, except as pertaining to the battery, for by this singleness of presentation the detail of technical adaptation and of manipulation can be followed in all the forms of battery which have had the sanction of former or present usage. There has resulted a book at once suited to the reader of books, to the student in science and to the operative electrician as interesting, instructive and authoritative in the subject treated.

It must not be supposed that any book can fill the place of teacher to those most advanced in the art, and it is somewhat to be regretted that this treatise had not been "edited" to cover the last form or prac-

tice in the United States. A few pages well illustrated would have been very appropriate. And without desiring to find fault it might be well that next edition be more carefully proof-read, although the errors are mostly in letters (Fig. 10 of the illustrations should be Fig. 12). Two hours work would correct the chemical notations throughout. The book wants an index badly.

These minor defects do not detract from the immediate value of the work, which is an indispensable addition to the English library of every one interested in any way with electrical science. B.

ENGINEERS' AND MECHANICS' POCKET BOOK. By Chas. H. Haswell. 12mo. New York: Harper & Brothers. 1880.

During the past thirty-seven years this valuable work has been one of the most useful pocket reference books in use, and has now reached its 36th edition in an enlarged and revised form. The first edition of 284 pages was published in 1848 and intended to supply a long felt want of a convenient reference to Rules, Results and Tables, and has supplied that want to an extent beyond what was anticipated. In order to adapt it still more fully to the use of engineers and mechanics it has been gradually enlarged to embrace very general information upon arithmetical, physical and mechanical subjects; typographical and other errors have been corrected as far as noticed by the author or when his attention has been called to them, and every effort made to render the work a reliable one.

Space will only permit a brief reference to a few of the additions and corrections to the last edition. The article on "Animal Strength" has been much enlarged and brought up to the present year; the same with "Passages of Steamers and Sailing Vessels." Proportions of "Cements;" equivalents of old U. S. and metrical measures; dimensions and performance of pumping engines; "railroad speed;" "Miscellaneous notes" embracing solutions of questions by a graphic operation, matter, volumes, etc., have been added. The change of position of several articles has caused some errors in the index which, however, can readily be corrected. R.

CIVIL ENGINEER'S POCKET BOOK. By John C. Trautwine. New edition, revised and corrected. 12mo. Philadelphia: E. Claxton & Co. 1880.

The fourteenth edition of this deservedly popular work is before

us. Originally written for civil engineers only, the vast amount of practical information condensed into it has made it equally a favorite with contractors, builders and machinists; beside leading to its adoption as a text book in many educational institutions.

Many new engineering facts are scattered throughout the volume; some subjects, such as "Cements and Concretes," "Rivets and Riveting," "Strength of Materials," "Iron" and "Wooden Pillars," "Trusses," "Railroads," etc., have been entirely rewritten or much altered; and those on "Buoyancy, Flotation, Metacenter," "Moments of Rupture and Resistance," "Kutter's Formula" for the mean velocity in feet per second in pipes, aqueducts, canals, rivers, "Open and Closed Beams," "The Shearing of Beams," "Test Borings," the valuable experimental results of C. Shaler Smith on "Eye Bars and Pins," "Velocities in Sewers," etc., are given for the first, time together with many new tables indespensible to engineers, builders and machinists.

The work is profusely illustrated with diagrams, explanatory of the most important formula, and the modern Engineer's Transit Instrument and Level as made by Heller and Brightly, Philadelphia, are now figured instead of the old-fashioned instruments, but we regret to notice, *without* their latest improvement—the Hoffman patent shifting tripod head.

Although the work was originally prepared specially for young members of the profession, it has been in most respects brought up to the present standard of civil engineering and experts will find it a most convenient work for ready reference, facilitated as it is by the improvement in the letter-press and insertion of much heavy black letter. R.

School and Industrial Hygiene. By D. F. Lincoln, M. D. 16mo. Philadelphia: Presley Blakiston. 1880.

This latest issue of the American Health Primers, so admirably edited by Dr. W. W. Keen, is in some respects the most important of the series, as it takes up school hygiene, in which so many thousands of parents in every large city are interested. In the chapter on the "Amount of Study," the author states that he does not believe the Kindergarten system injurious to a child of four years, unless carried to the point of over-excitement, which is not often done; but the common primary school is decidedly objectionable. It takes very young children, and compels them to remain twice as long as is good for

them. By great ingenuity and vivacity, a teacher can keep them upon various studies for three hours. This is all that is reasonably possible, yet the children are expected to come back for a second session in the afternoon. He concludes by stating that a school conducted by lessons and recitations—a mimic grammar school in fact—should not receive children under seven or eight years of age. The chapters on the "Care of the Eyes" and "School Desks and Seats" are very important; while the second part of the work takes up "Industrial Hygiene," and, after treating of the injurious effects of inhaling dust, poisonous substances, etc., the author treats of those from atmospheric changes, over-use of certain organs and accidents. Chapters on the regulation of hours of labor, and the duration of life in various occupations, are then given. A full index completes this very interesting little volume, which can hardly fail to be extensively read. N.

THE CARPENTER'S STEEL SQUARE AND ITS USES. By Frederick T. Hodgson. Square 16mo. New York: Industrial Publication Co. 1880.

This little work consists of a republication of some papers contributed by its talented author some time ago to the *American Builder*, and which were received with so much favor by artisans, for whom they were written, as to induce their author to collect them into the present volume. It is not claimed that the rules and methods herein stated are original with him, but only that they have never been brought together before in so handy a volume. The work is well illustrated by upwards of fifty cuts which have been well engraved, and can hardly fail to give any one an idea of the capabilities of the steel square and what can be accomplished from it in skillful hands. N.

AMERICAN NEWSPAPER DIRECTORY. 8vo. New York: Geo. P. Rowell & Co., Publishers. 1880.

In this large volume of 1044 pages we have a complete list of the various newspapers and periodicals published in the United States and Canada, arranged alphabetically by States and places of publication, the population, location and prominent industries, etc., being also indicated. Such a list is exceedingly valuable, and as it is revised and printed every year must be up to date. Pains seem to be taken to make it as complete as possible, and the only fault that can be found with it is in the statement of the circulation of any publication, which after all, must be a matter of conjecture, except with the publisher. We know of no other work in which so much information on the above topics can be obtained. N.

Influence of Electricity on Vegetation.—In bamboos the flow of sap takes place at the beginning of the rainy season, but vigorous shoots rarely grow before the thunder-storms, which generally precede the harvest. The rapidity of their growth increases with the violence of the storm, amounting sometimes to as much as 70 feet in 30 days, the vegetation being most active during the night. Captain Sleeman suggests that the cause of this sudden growth may be the increase in the quantity of nitrogenous compounds, which are greedily absorbed by the humus that surrounds the roots of the bamboos. The facts offer a curious confirmation of the experiments of Dr. Siemens upon the influence of electricity on vegetation.—*Les Mondes.* C.

Boiler Scale.—M. Lodin has found that the predominant action upon boilers is due to the oxygen of the air which is dissolved in the water, and that this action, contrary to the general opinion, is slightly greater with calcareous waters than with distilled water. A second cause of oxidation, of much less importance, is the decomposition of the water by the iron. This also is a minimum with pure water. The scale deposits can only adhere to a surface in which oxidation has commenced, and the most efficient disencrustants, such as zinc, are those which prevent the oxidation of the boiler plates. Campeachy wood, potato starch, and some other ingredients, owe whatever efficiency they possess to the formation of compounds with the oxide of iron, which have little adhesive power, and can therefore be easily removed.—*Comptes Rendus.* C.

Electro-Dynamic Paradox.—M. Gérard-Lescuyer has discovered a novel phenomenon, by sending the current produced by a dynamo-electric machine into a magneto-electric machine. As soon as the circuit is closed the magneto-electric machine begins to move; it tends to take a velocity proportioned to the intensity of the originating currents, but it soon moves more slowly, stops, and turns in the opposite direction, going through a similar series of changes and returning to the first direction. This regular alternation of movement continues as long as the originating current is in action. In trying the experiments a Siemen's dynamo-electric machine, with continuous currents, was used as the generator. The receiver was a small laboratory Gramme machine, with an ordinary permanent magnet, constructed by M. Breguet.—*Comptes Rendus.* C.

Decomposition of Carbonic Anhydride by Magnesium.—Upon plunging a fine burning wire of magnesium into a large glass cylinder filled with carbonic acid, the metal continues to burn with a brilliant white light and to throw out brilliant sparks in all directions. Carbon is soon deposited upon the walls of the cylinder, while the heavier magnesia falls to the bottom of the vessel. The phenomenon forms a very interesting lecture experiment.—*Polyt. Notizbl.* C.

Celluloid Stereotypes.—Emile Jeannin, a French sculptor, being impressed by the malleability of celluloid at 125°C. (2570°F.) thought of using it for stereotype plates. The electrotypes from wood engravings require long and complicated operations. The plates which are made from celluloid can be prepared in half an hour, and they are very sharp, very strong, very light and very flexible, so that they can be successfully, readily and usefully applied to the surface of the cylinders of fast presses.—*Les Mondes.* C.

False Meteorites.—In the collection of meteorites which M. Daubrée is making he is obliged frequently to decide upon the authenticity of specimens which are forwarded to him. Some of them come from men of distinguished scientific ability and accustomed to observation, such as Le Verrier, Becquerel, Antoine Passy, Marshal, Vaillant, and yet the collectors are deceived in spite of their skill. There are various reasons for this deception. The luminous and acoustic effects of lightning, in some cases, may be confounded with the explosion of bolides, and it is natural that a stone picked up in the neighborhood of a point where the meteor seemed to fall, should be taken, if it is different from the neighboring rocks, for a mass fallen from the sky. The mistake is the more easy because, by an inevitable illusion, one always seems to be near the point of fall, even when he is miles away from it, This remark is especially applicable in the case of a bolide, or of a shooting star, which is followed by a luminous train, and which seems to fall vertically upon the ground. Sometimes, in cretaceous districts, balls of radiating pyrites are found, which are so changed by disaggregation as to differ completely in appearance from the ordinary rocks. In consequence of these frequent errors Daubrée urges the importance of caution in accepting any statements about the fall of bodies until specimens have been carefully examined.—*Comptes Rendus.* C.

Electric Fishing.—An electric fish-hook has excited much attention and curiosity at the Berlin exposition. It is attached to a little skiff, which can be directed noiselessly towards any point of the water by means of a helix and wheel work. When reaching the desired location it anchors itself against wind and stream while the line and hook glide into the water. The skiff contains an electric battery and an induction coil, so arranged that the slightest bite completes the electric circuit. Immediately, with the rapidity of a flash, under the action of an electro-magnet, the line, hook and fish are raised into the air; a little bell rings to inform the fisherman of the capture, so that he can draw the skiff ashore and detach the fish.—*Les Mondes.* C.

Contact Electricity.—F. Exner attributes the electricity which is developed by the contact of two metals to the difference of the chemical actions of the surrounding medium upon the metals, and he thinks that the quantities of electricity are proportional to the heats of oxidation, as in hydro-electric couples. The experiments of De la Rive show that there is no charge in a vacuum or an inert gas, moreover, the orders of oxidation and of electric tension in the air are identical. The heats of combustion are well known, but there is a great divergence between the values which have been given to electric tensions by different authors. Exner employs a new condenser to measure them, and finds a remarkable accordance between the observed and calculated values. The chemical theory accounts readily for all the observed effects, but the contact theory is insufficient in many cases.—*Wied. Ann.* C.

Franklin Institute.

HALL OF THE INSTITUTE, September 15th, 1880.

The stated meeting was called to order at 8 o'clock P. M., the President, Mr. William P. Tatham, in the chair.

There were present 86 members and 15 visitors.

The minutes of the last meeting were read and approved.

The Actuary presented the minutes of the Board of Managers, and announced that 26 persons were elected members of the Institute at he July meeting and 12 at the August one.

The Secretary reported the following donations to the Library:

Eleventh Annual Report of the U. S. G. and G. Survey of Territories for 1877. By F. V. Hayden. From the Author.

Council Book of the Corporation of Youghal from 1610–1800. By R. Caulfield. Surrey, 1878. From the Author.

Annales of Astronomical Observatory of Harvard College. Vol. 12. By W. A. Rogers. Cambridge, 1880.

Catalogue of 618 Stars, observed at Astron. Observatory of Harvard College. By W. A. Rogers. Cambridge, 1880.

Contributions to our Knowledge of the Meteorology of the Artic Regions. Part 2. London, 1880.

Meteorological Observations at Stations of Second Order for year 1878. London, 1880.

From the Meteorological Committee of the Royal Society.

Report of the U. S. Survey of the Territories. F. V. Hayden in charge. Vol. 12. Fresh Water Rhizopods of North America. By Dr. Jos. Leidy. Wash. Gov't, 1879.

From Dr. F. V. Hayden.

Astronomical Papers prepared for use of American Ephemeris and Nautical Almanac. Vol. 1, Part 2. Wash. Gov't, 1880.

From Bureau of Navigation, Navy Dep't, U. S.

Memoirs of Geol. Survey of India. Palæontologia Indica. Ser. 14, Vol. 1, Part 1. Calcutta Gov't, 1880. From the Survey.

Smithsonian Miscellaneous Collections. Vols. 16 and 17. Washington, Inst., 1880.

Smithsonian Contributions to Knowledge. Vol. 22. Wash., Inst., 1880. From the Institution.

Report upon U. S. G. Surveys west of 100th Meridian. Vols. 2, 4 and 6. From Lieut. G. M. Wheeler.

Report of the Supt. of U. S. Coast Survey for 1876. Wash. Gov't, 1879. From the Survey.

Report of Department of Public Works of New York City. Mar. 31, 1880. From the Department.

Proceedings of 28th Meeting of Board of Supervising Inspectors of Steam Vessels. Wash. Gov't, 1880 From the Board.

Iron and Steel Works of the United States for 1880.

From the Iron and Steel Association, Philadelphia.

Fifty-first Annual Report of the Board of Commissioners of Public Schools. Baltimore, 1879. From the Commissioners.

First Annual Report of the Department of Statistics and Geology of Indiana. 1879. From John Collet, Chief of Bureau.

History of Bunker Hill Monument Association during 1st Century of United States of America. By G. W. Warren. Boston, 1877. From the Association.

Catalogue of Trees and Shrubs in Horticultural Hall Gardens, Fairmount Park. From the Horticultural Society.

Thirteenth Annual Report of the Peabody Institute of Baltimore, 1880. From the Institute.

Catalogue of the Library of the Geological Society of London. 1880. From the Society.

List of Vertebrated Animals in the Gardens of the Zoological Society of London. 1879. From the Society.

Microscopists' Annual for 1879. From Industrial Pub. Co., New York.

Indian Meteorological Memoirs. Vol. 1, Parts 3 and 4.
Report of Administration of the Meteorological Department of the Gov't of India in 1878 and 1879.
From Meteorol. Reporter of Gov't of India.

Testimony at Coroner's Inquest ot St. Charles Bridge Disaster of November 8th, 1869. By S. H. Younge. From the Author.

Report on Plans for Warming and Ventilating Bridgeport Schoolhouse. By R. Briggs. From the Author.

Circulars and Pamphlets pertaining to Exhibitions. From L. S. Ware.

Annual Report of Chief of Engineers, War. Dept., 1879. Wash. Gov't, 1880. 3 Parts. From Chief of Engineers.

First Annual Report of the State Board of Health, etc., of Massachusetts, 1879. Boston, 1880. From the Board.

Annual Reports of the Inspectors of Mines of the Anthracite Coal Regions of Penna. for 1878 and 1879. From the Inspectors of Mines.

Annual Report of the Board of Regents of Smithsonian Institution for 1878. From the Institution.

Annual Report of the Commissioner of the General Land Office for the fiscal year ending June 30th, 1879. From the Commissioner.

Annual Report of the Chief Signal Officer to the Secretary of War for the year 1879. From the Secretary.

Industrial Progress in Gold Mining. By G. W. Baker. From the Author.

Circulars of Information of the Bureau of Education. Nos. 2 and 3. 1880. From the Commissioner.

Patent Office Reports. Agriculture, 1854–1856 and 1858 and '59. Mechanics. Vols. 1 and 2. 1855.

Catalogue of British Section of the International Exhibition. Philadelphia. 1876.

Catalogue of Chinese Imperial Maritime Customs Collection at U. S. International Exhibition. Philadelphia, 1876.

Der Buchhandel und die graphischen Künste Deutschlands auf der Weltausstellung zu Philadelphia, 1876.

Catalog de los Expositores de España. Philadelphia, 1876.

International Exhibition, 1876. Official Catalogue. Dept. 4.

Œuvres d'Art et Produit Industrielles de France.

Mortality Statistics of the Census of 1850.

From Dr. Carl Hering, Philadelphia.

Speeches and Forensic Arguments. By D. Webster. Boston, 1880.

Journal of Franklin Institute, 1837 and 1838.

The Bible in Spain. G. Burrow. 1843.

Patent Office Reports, 1851 and 1852.

Diplomatic and Official Papers of Daniel Webster. 1848.

Elements of Surveying. C. Davies. 1836.

Treatise on the Principal Mathematical Instruments. By F. W. Summs.

Life of Galileo. 1835. From B. B. McKinley.

Second Treatise on Decrease of Water in Springs, Creeks and Rivers. From Chief of Engineers, U. S. A.

Mr. Tatham announced that a life-size crayon portrait of the late Secretary, Mr. J. B. Knight had been made during the summer, and he would be pleased to hear from any one on the subject.

Mr. J. Snowden Bell offered the following resolutions which were adopted unanimously:

WHEREAS, We, the members of the Franklin Institute, have heard, with great pleasure, that this institution has been presented with a portrait of its late Secretary, Mr. J. B. Knight, therefore be it

Resolved, That we receive with thanks this pleasing memorial of Mr. Knight.

Resolved, That we hereby request the proper authorities of the Institute to place this gift in some prominent position in the rooms of the Institute, as a fitting tribute of respect to the memory of one who so earnestly labored in behalf of the purposes of this institution.

Mr. W. Barnet Le Van read a paper, illustrated by diagrams and drawings, on "The Weakening of Steam Boilers by cutting holes in the shell for domes and necks." He said that the weakening effect of cutting holes for domes or necks was proportioned to the section of the

dome joining the shell, independent of the size of the hole cut, and expressed the opinion that domes should be discarded and boilers of slightly larger diameter, with perforated tubes, used, instead of boilers with domes. He cited instances of the successful use of locomotive and stationary boilers constructed without domes. He contended that manholes should never be cut in the shell if it was possible to avoid doing so, and described at length experiments made by the Manchester Steam Users' Association in 1876, in support of his statements. He referred to the bad record made by the "two-story," or "Rider" boilers, such as exploded in Cherry street in 1864, and the one at Wilt & Sons' mills, which burst last year. He considered the form dangerous, and doubted whether it was as economical as had been claimed, and also said that "outside of a radius of thirty miles of this city they are scarcely known." The boilers tested by the Manchester Steam Users' Association were analogous in construction to the "two-story," or "Rider" boilers.

The diagram of a boiler containing the perforated pipe suggested by Mr. Le Van was thrown upon the screen, and some discussion arose as to the proper position of the pipes as shown in the diagram, in which Messrs. Cooper, Nystrom, Bell, Cartwright and Le Van participated.

Mr. Bell called attention to an inaccuracy in the paper read by Mr. Le Van, which he had seen mentioned elsewhere, and that was in regard to the use some years ago on the Baltimore and Ohio Railroad of locomotives without steam domes. He had been connected with the road at the time mentioned (from 1860 to 1865), and they had at the time eight Mason engines, all of which had steam domes.

Mr. Le Van said that there were some roads in England successfully using locomotives without steam domes.

Mr. Orr, referring to a statement in Mr. Le Van's paper about a boiler which was being tested, and which, after standing a pressure of 149 pounds, burst at the addition of another pound, expressed the opinion that a safe limit of test should be adopted to prevent such explosions.

Dr. Seiler exhibited and described a photophone, in which a ray of light, passing through perforations in a revolving disk, and being thus interrupted, transmitted a sound proportioned to the velocity of the disk, to any substance except carbon or fine glass. He also gave an account of Prof. Bell's experiments which led to the invention of the

photophone. Selenium, in its crystalline form, when exposed to light, opposes less resistance to the passage of an electric current than when in darkness. Prof. Bell made a cell of selenium, and introduced it in the primary coil of an induction coil, the secondary coil being connected with a telephone. He then took a disk of silvered mica, condensed on it the sunlight, and throwing the reflected light, condensed by a lens, upon the selenium cell, made the beam of light and interrupted one by speaking against the mica disk, and setting up vibrations, which changed its form. The varying resistances offered by the selenium to the passage of the current resulted in movements of the disk of the telephone in circuit therewith, corresponding with the variations produced by speaking against the mica disk at the other end of the beam of light. The photophone had been tried at a distance of 900 feet—far enough apart to make it certain that the voice of the speaker could not be heard without the use of the photophone—and conversation had been successfully carried on. Dr. Seiler said that he had had satisfactory experiments with it over a distance of about sixty feet. He considered it an instrument of extreme scientific interest, but did not know whether it would be of any practical value. The medium of transmission is not heat, nor light in conjunction with heat, for an alum cell has been used to cut off the heat rays. In the simple instrument which he exhibited one could hear the sound of the interrupted beam of light without the use of the diaphragm, and that the sound was not an imaginary one could easily be tested by putting the hand in the beam of light, thus interrupting the sound.

Mr. Cooper inquired why, with a mechanical arrangement of this kind, carbon or glass could not be used.

Dr. Seiler replied that very little was known as yet about this new instrument. There are many obscure facts about its operation. All that observers can now do is to report facts as they find them, and it appears from experiments that some substances are better than others. He would not say that glass or carbon would not respond by sound to the interruptions of the beam of light, but only that they were not as good as some other substances—hard rubber for instance.

Prof. Houston said that this was one of the most wonderful discoveries ever made. He had not had the advantage of seeing the experiments described in the garbled reports of newspapers, but he nevertheless felt competent to make a photophone from what he knew about the principles on which they are constructed. They may be aptly